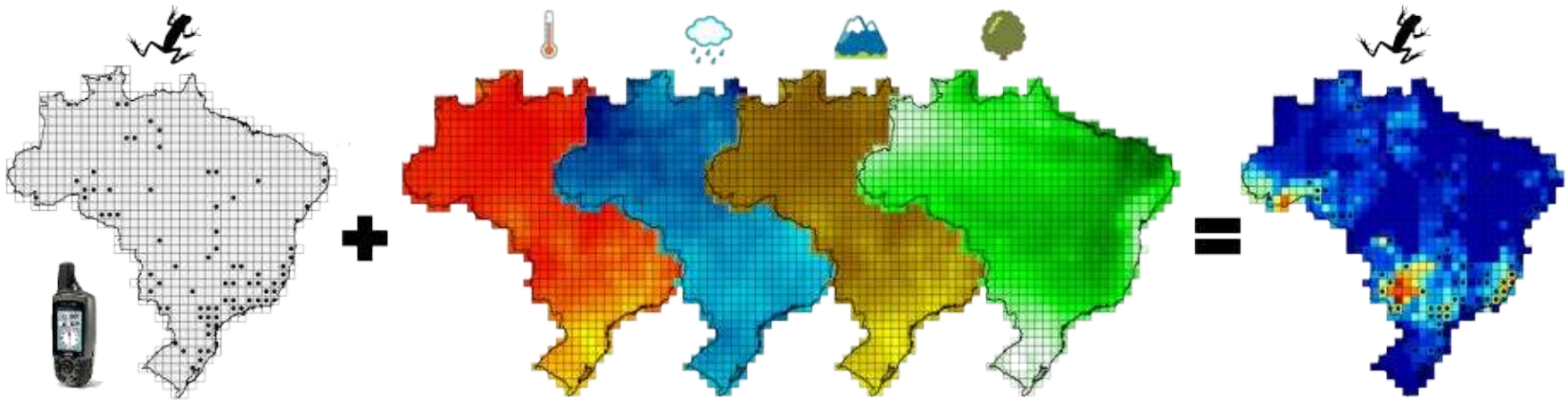
# Modelos de Distribuição de Espécies: uma visão geral



Maurício Vancine

05/03/2020

Grupo de Genética e Genômica da Conservação
APTA

USP
ESALQ

# Palestra

## Tópicos

1. Apresentações
2. Introdução aos Modelos de Distribuição de Espécies - *Species Distribution Models* (SDMs)
3. Nicho Ecológico e Distribuição das Espécies
4. Construção dos SDMs passo a passo
5. Dados de entrada: ocorrências e variáveis ambientais
6. Ajuste dos modelos
7. Avaliação dos modelos
8. Predição dos modelos
9. Aplicações e mais informações

# 1. Apresentações

# Maurício Vancine

## Ecólogo (2015) | Mestre em Zoologia (2018) | Doutorado em Ecologia (2020-?)

**Pesquisa**

Ecologia Espacial (Ecologia da Paisagem)
Ecologia Quantitativa (SDM e JSDM)
Ecologia e Conservação de Anfíbios

unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"

**Especialidades**

Modelos de Distribuição de Espécies (SDMs)
Análise de Dados Ecológicos e Geoespaciais
Open source [R, QGIS, GRASS GIS, Linux, Libreoffice, ...]

**Contato e informações**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@mauriciovancine
mauriciovancine.netlify.com

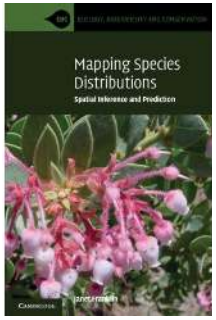
# 2. Introdução aos Modelos de Distribuição de Espécies (SDMs)

# Uma abordagem, muitos nomes...

*Ecology*, 93(7), 2012, pp. 1527–1539


Uses and misuses of bioclimatic envelope modeling

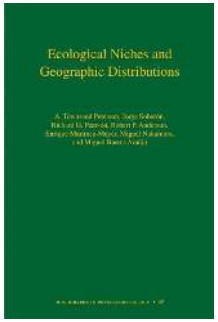
MIGUEL B. ARAÚJO[1,2,3,5] AND A. TOWNSEND PETERSON[4]




Franklin (2009)

1. **Modelos de Envelopes Climáticos** (*Bioclimatic Envelope Models*)
Estimado um espaço multivariado de variáveis climáticas (envelope)

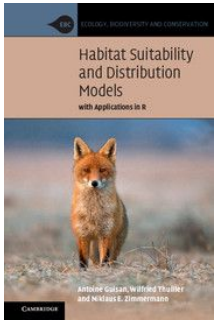
2. **Modelos de Nicho Ecológico** (*Ecological Niche Models*)
Vincula o envelope à teoria de nicho ecológico (Grinnell e Hutchinson)




Peterson et al. (2011)

3. **Modelos de Adequabilidade de Habitat** (*Habitat Suitability Models*)
Envelope relacionado ao “habitat”, como espaço físico e recursos

4. **Modelos de Distribuição de Espécies** (*Species Distribution Models*)
Modelar a distribuição geográfica das espécies

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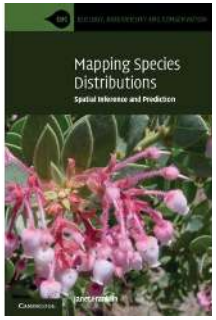


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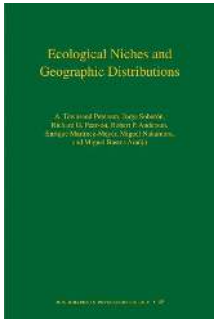


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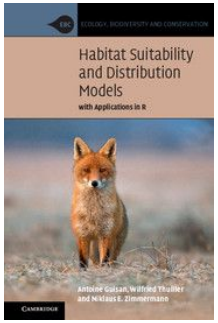
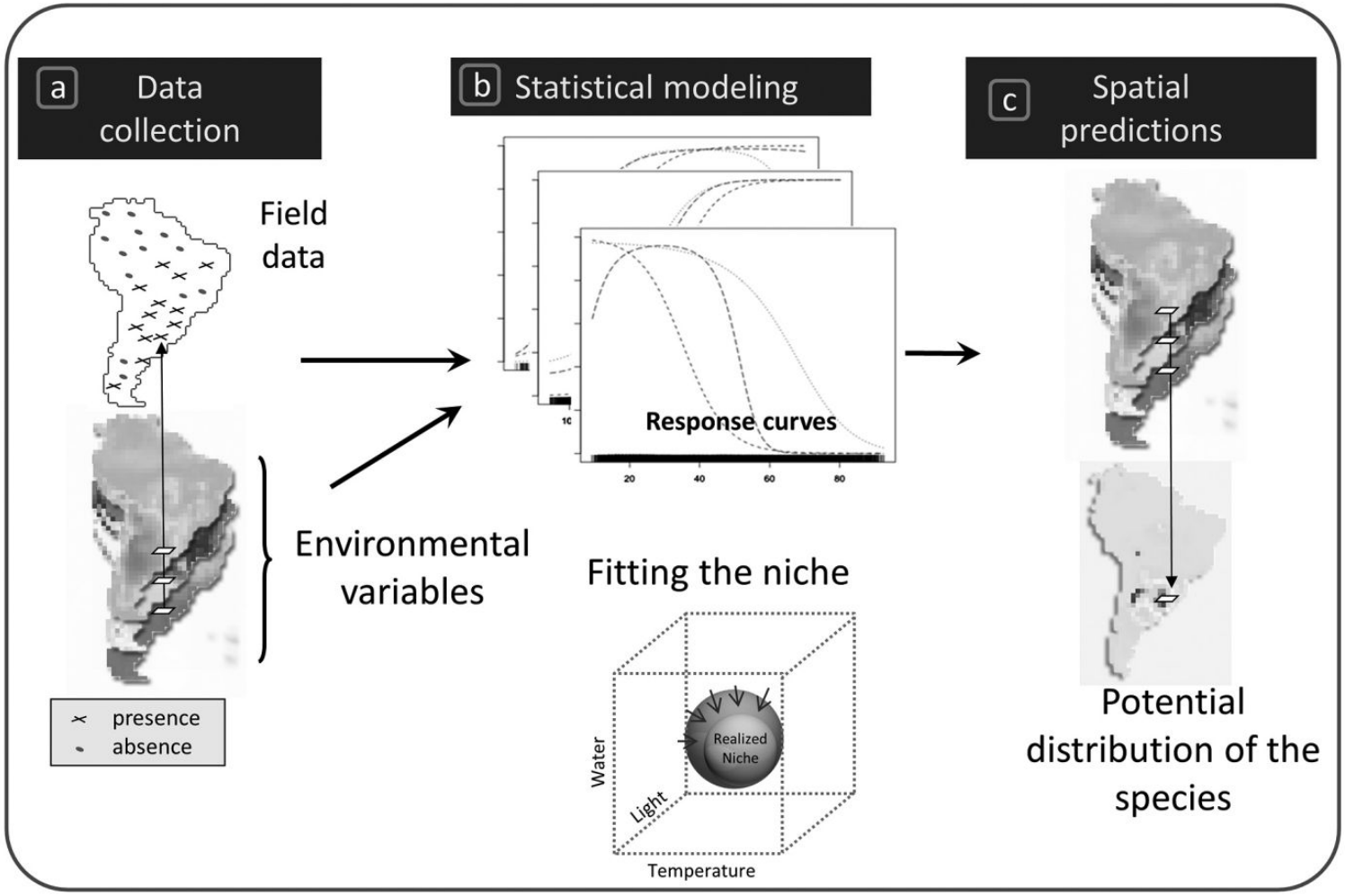
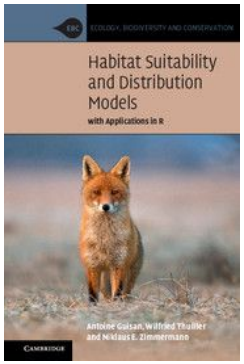



Guisan et al. (2017)

# Modelos de Distribuição de Espécies (SDMs)

## Visão geral

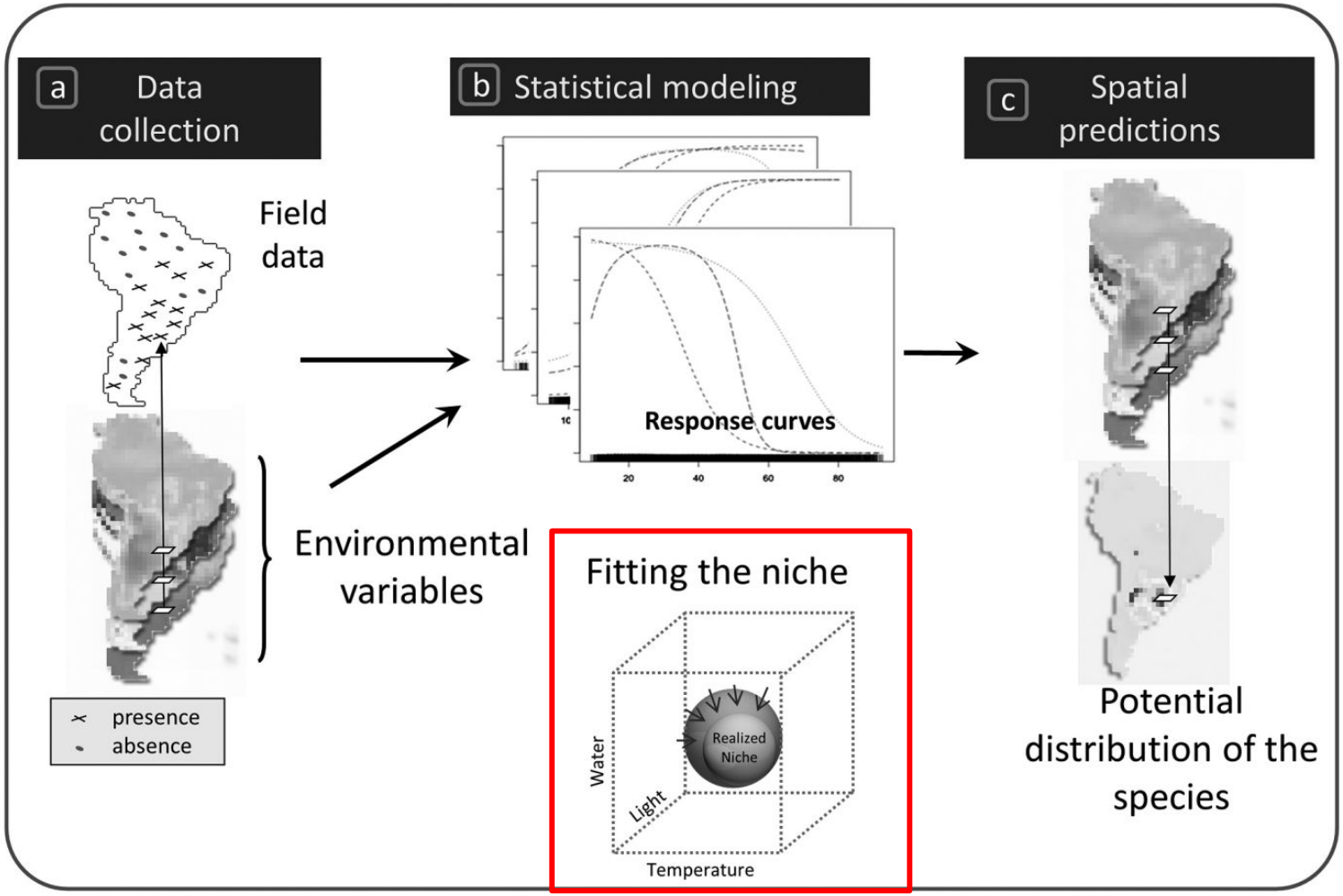


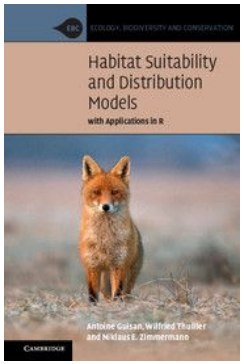




Guisan et al. (2017)

# Modelos de Distribuição de Espécies (SDMs)

## Visão geral



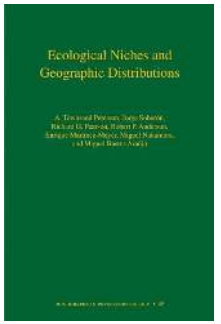

Guisan et al. (2017)

# 3. Nicho ecológico e distribuição das espécies

# O que determina a distribuição das espécies?

## Espaço Geográfico (G)

**G**




Peterson et al. (2011)

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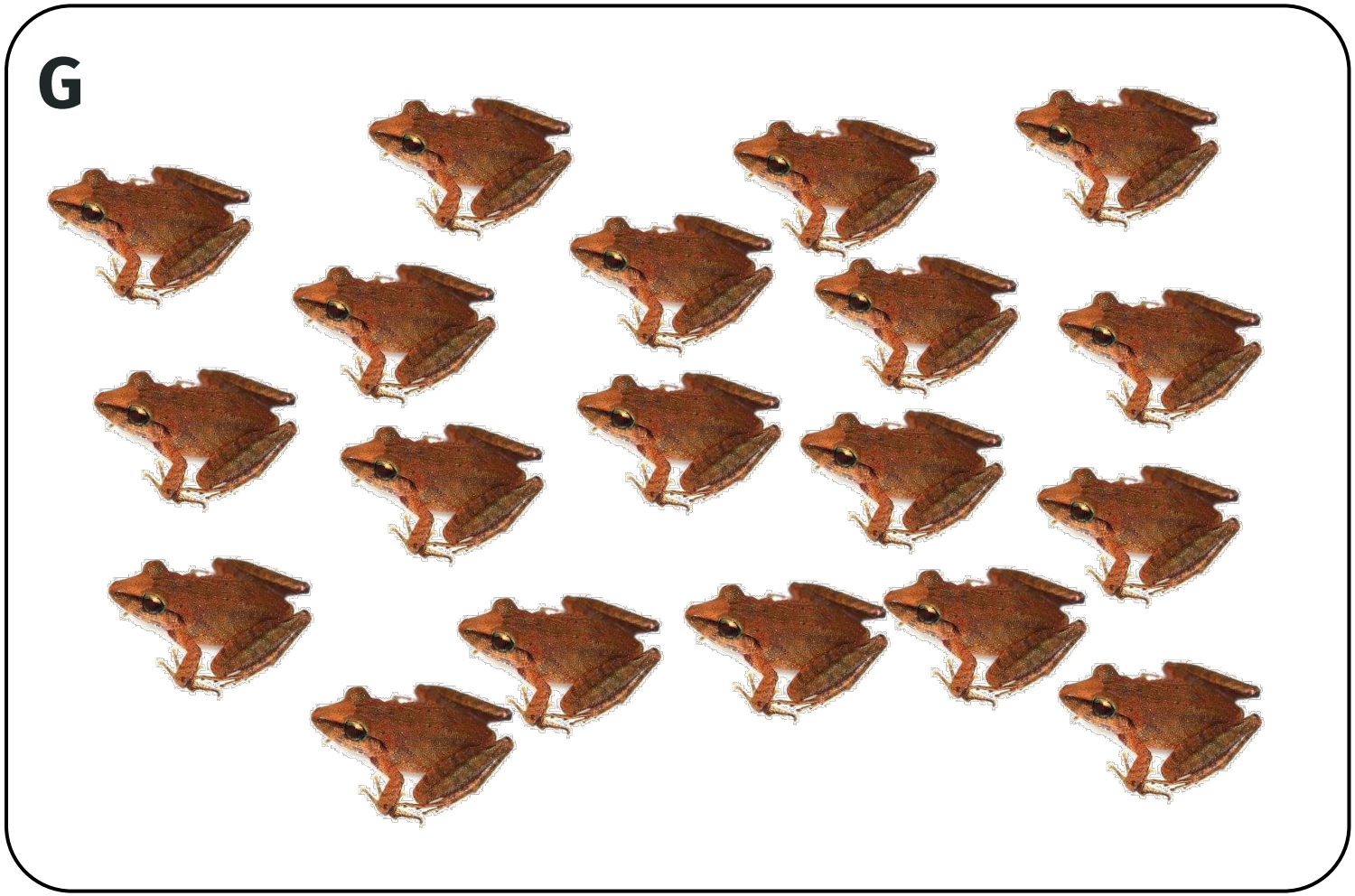
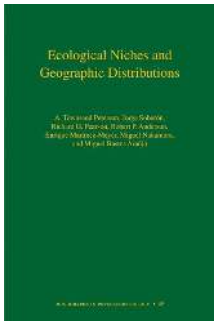
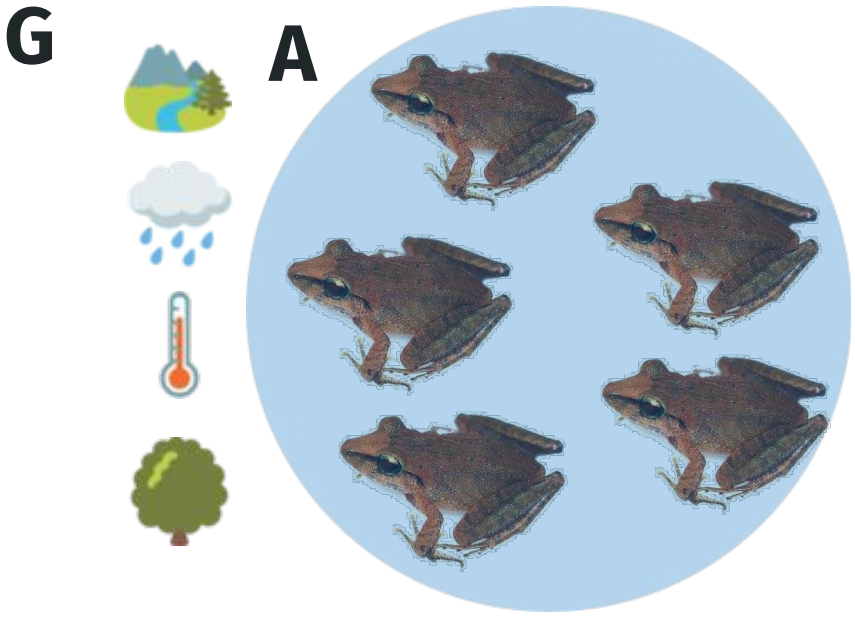


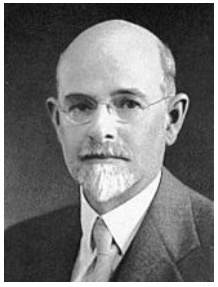




Peterson et al. (2011)

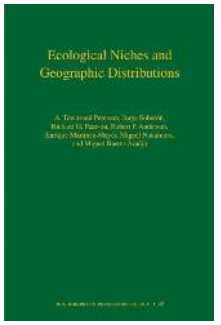
# O que determina a distribuição das espécies?

## Condições Abióticas (A)



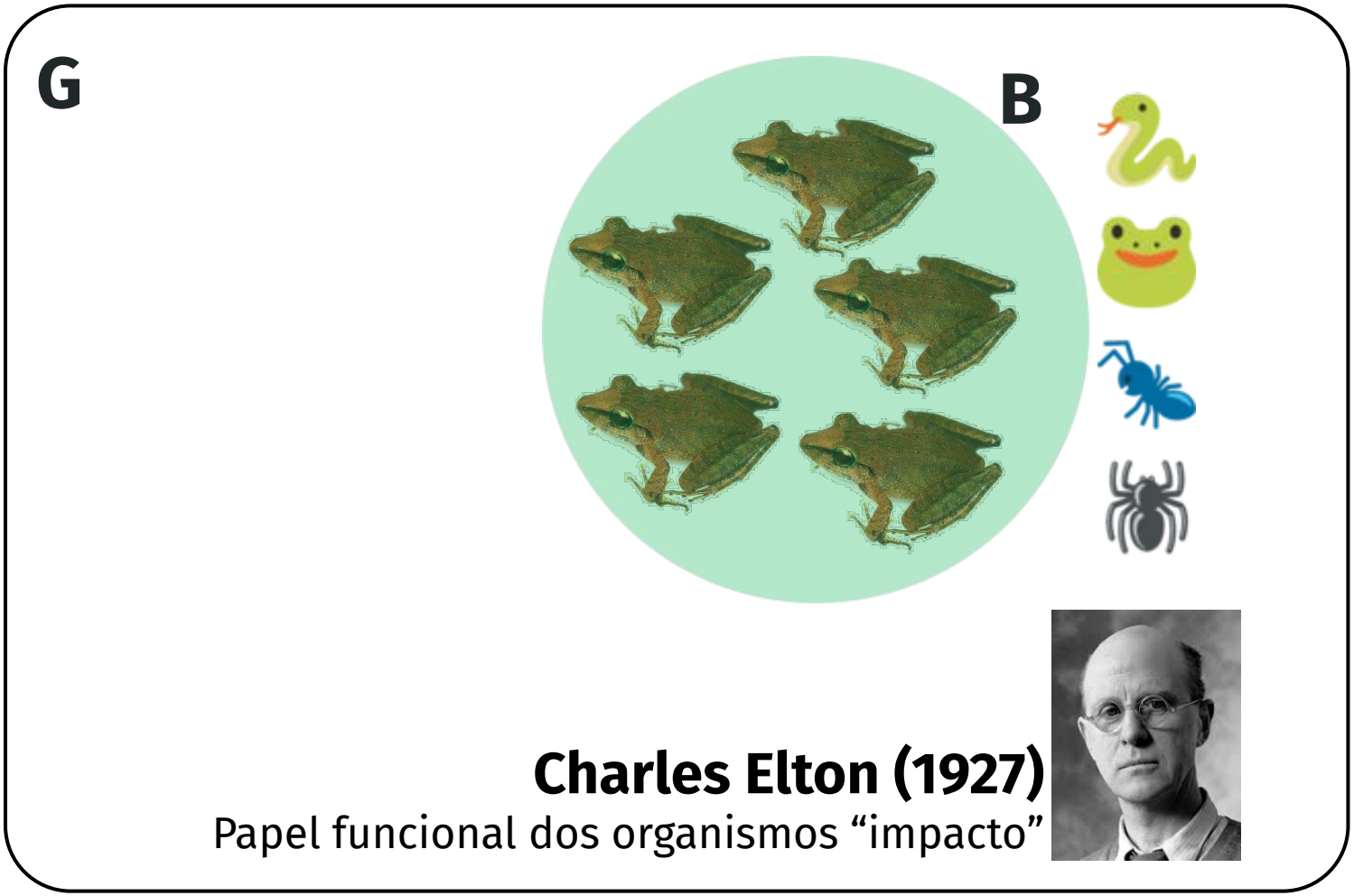
**Joseph Grinnell (1917)**
Requerimentos ambientais “condições climáticas”




Peterson et al. (2011)

# O que determina a distribuição das espécies?

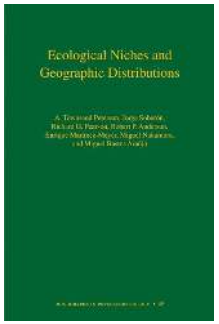
## Condições Bióticas (B)




**Charles Elton (1927)**

Papel funcional dos organismos “impacto”

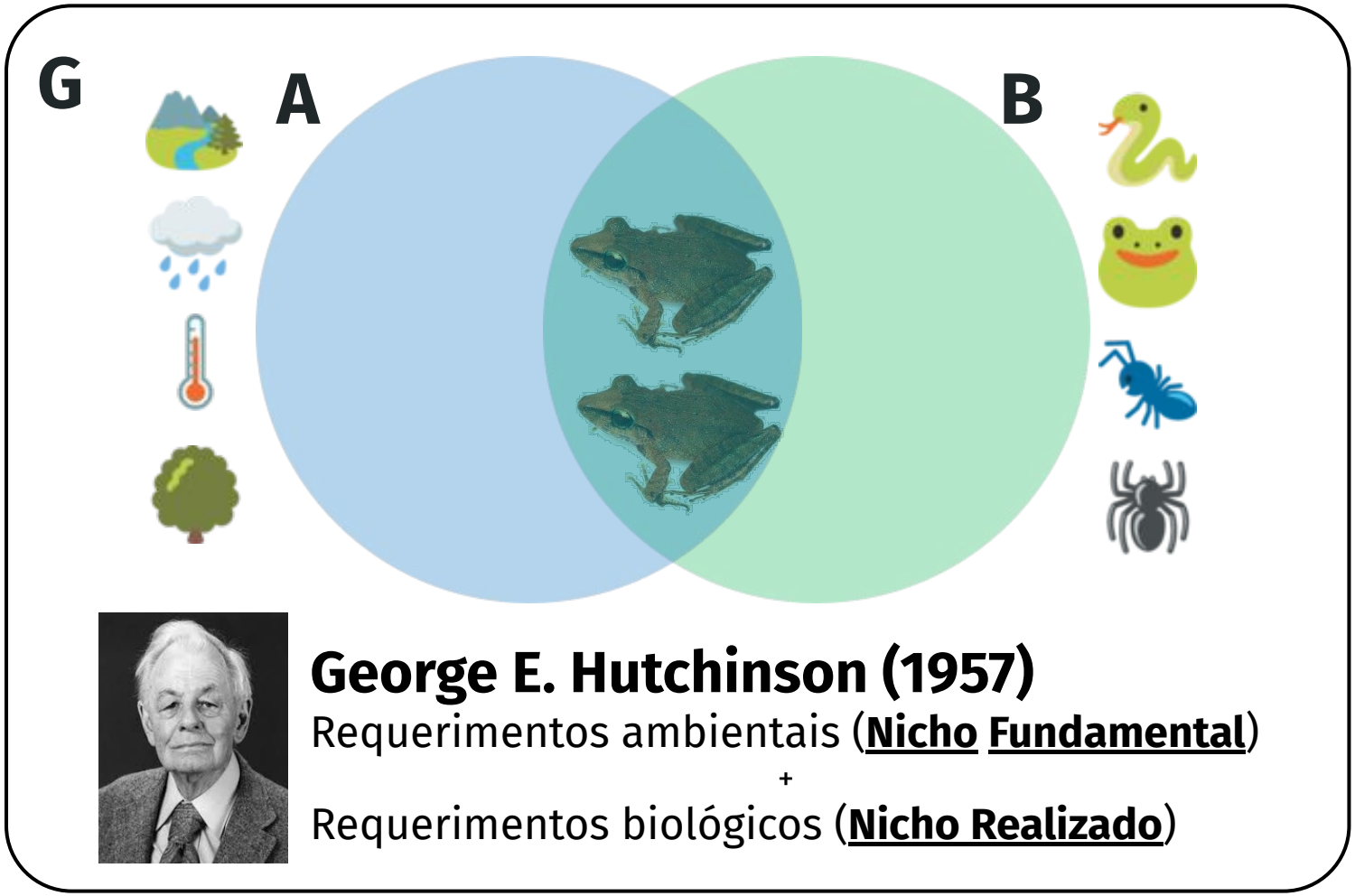





Peterson et al. (2011)

# O que determina a distribuição das espécies?

## Relação entre condições abióticas e bióticas



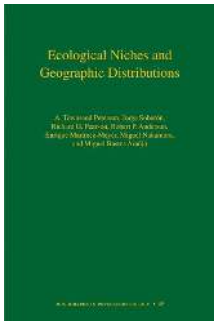



**George E. Hutchinson (1957)**

Requerimentos ambientais (**Nicho Fundamental**)

+

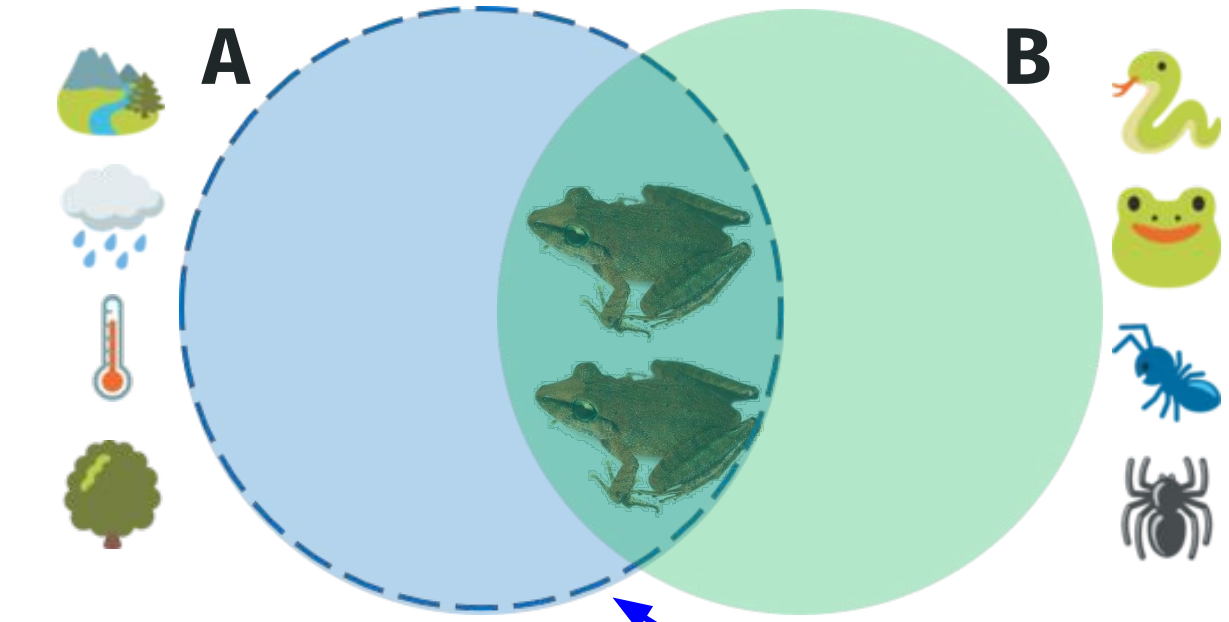
Requerimentos biológicos (**Nicho Realizado**)

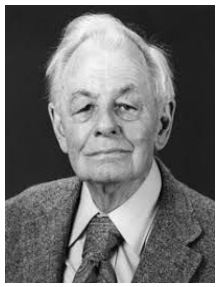



Peterson et al. (2011)

# O que determina a distribuição das espécies?

## Nicho Fundamental



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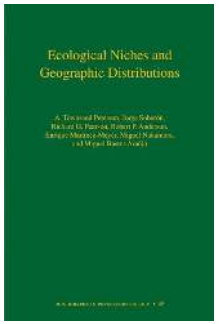
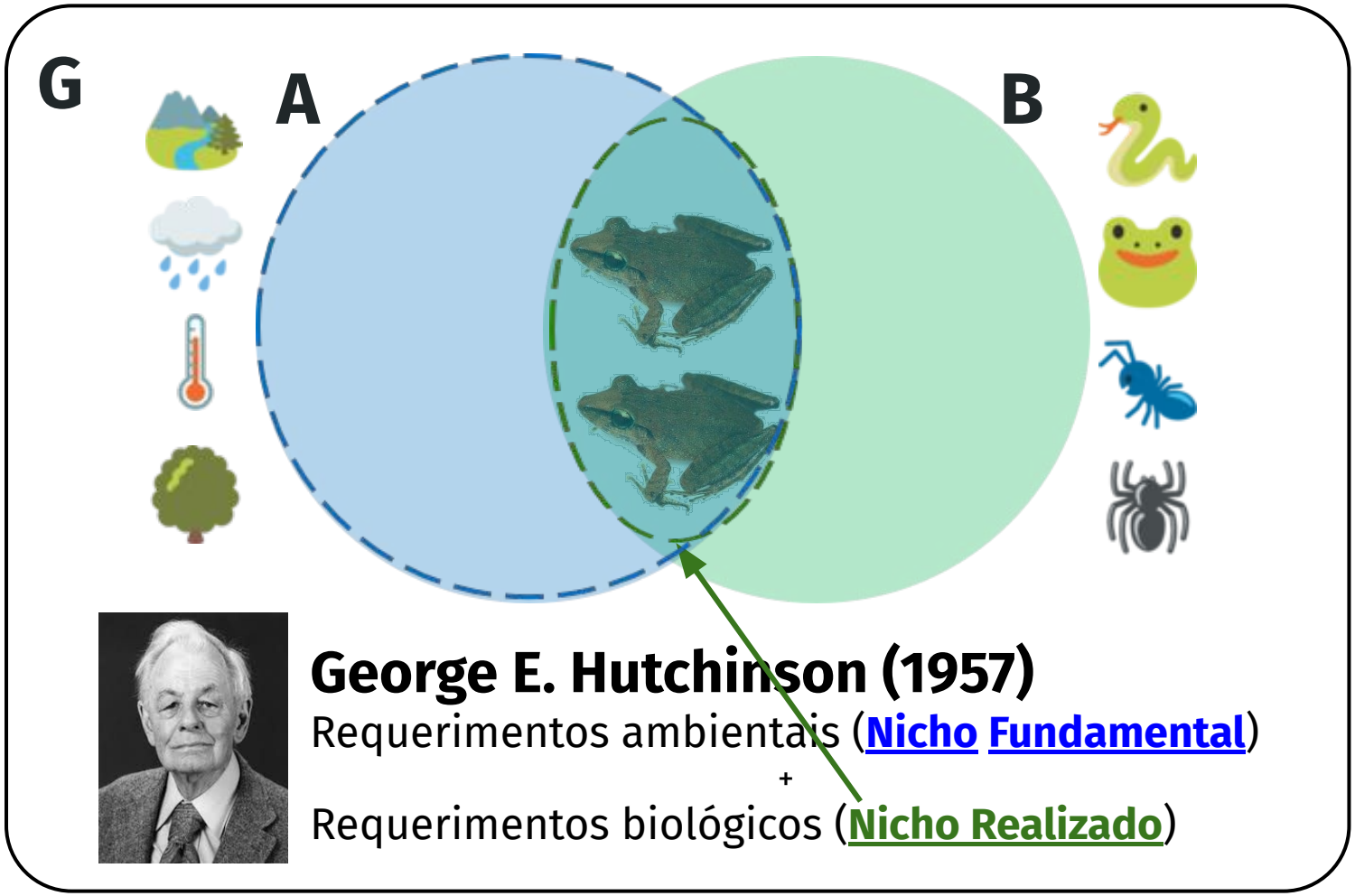
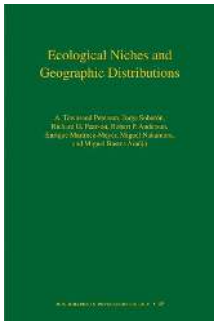



Peterson et al. (2011)

# O que determina a distribuição das espécies?

## Nicho Realizado

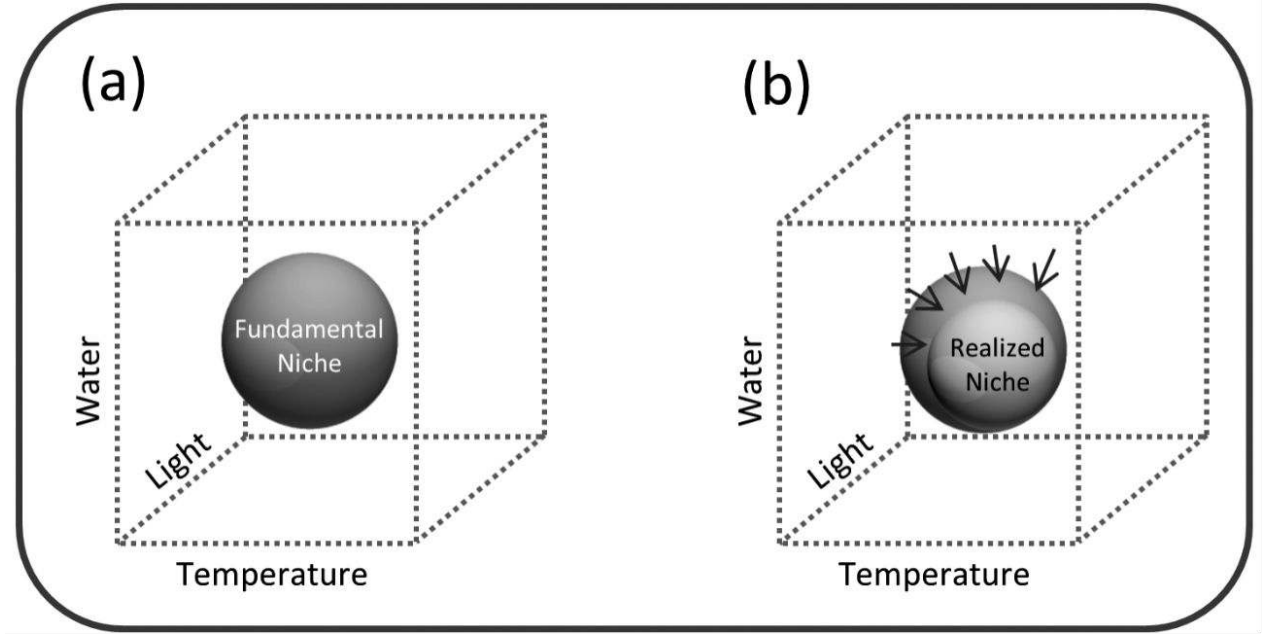


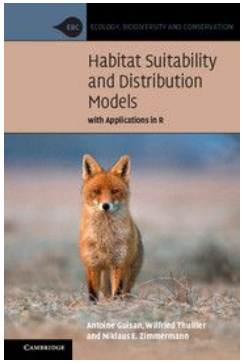




Peterson et al. (2011)

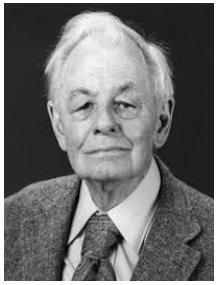
# O que determina a distribuição das espécies?

## Hipervolume n-dimensional




Guisan et al. (2017)



**George E. Hutchinson (1957)**

Requerimentos ambientais (**Nicho Fundamental**)

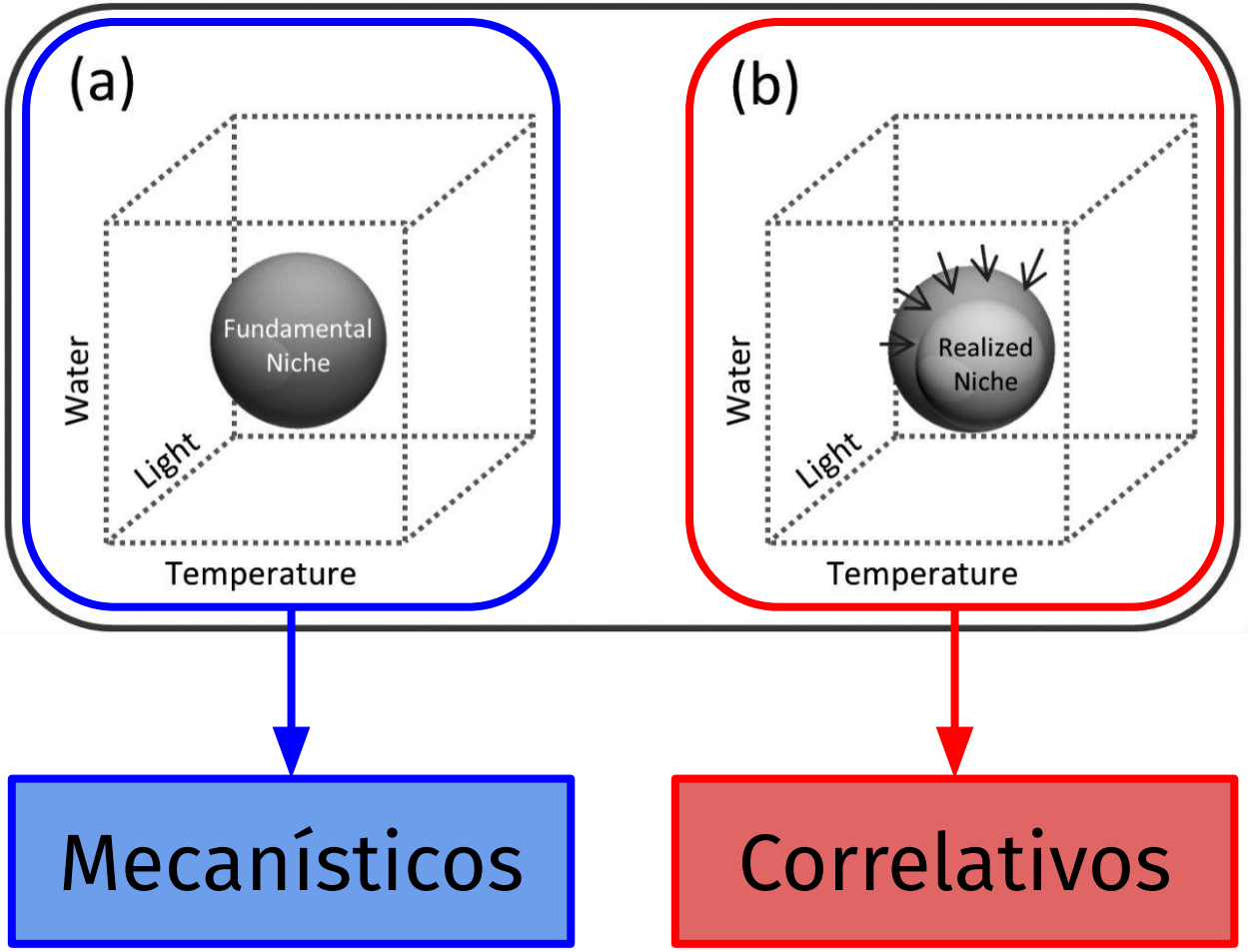
+

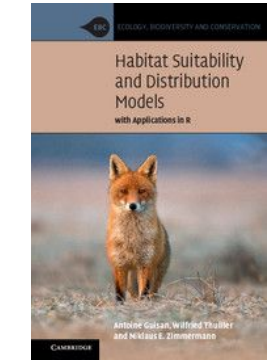
Requerimentos biológicos (**Nicho Realizado**)

Os SDMs estimam o nicho **fundamental** ou **realizado**?

# Nicho fundamental e realizado

## Modelos mecanísticos e correlativos

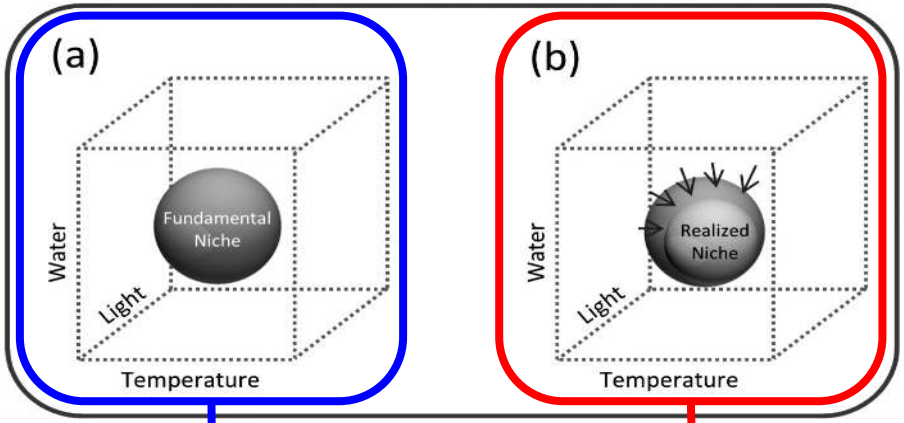


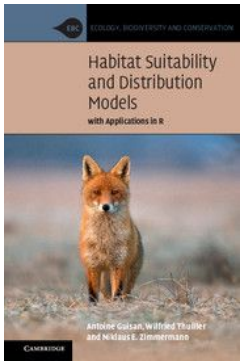




Guisan et al. (2017)

# Nicho fundamental e realizado

## Modelos mecanísticos e correlativos

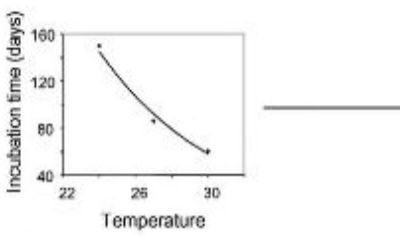


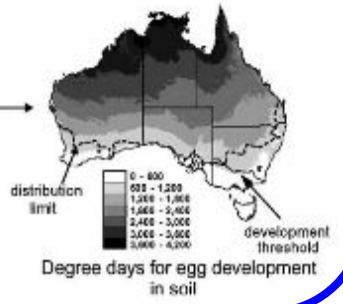

Guisan et al. (2017)

### Mecanísticos

GIS data
Organismal data (behaviour, morphology, physiology, life history)
→ Mechanistic niche model → Predicted distribution (fitness/fitness components)



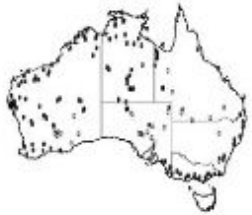

*Heteronotia* egg development



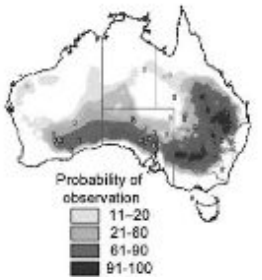

Degree days for egg development in soil

### Correlativos

GIS data
Distribution data (presence/absence)
→ Correlative habitat model → Predicted distribution (probability of occurrence)

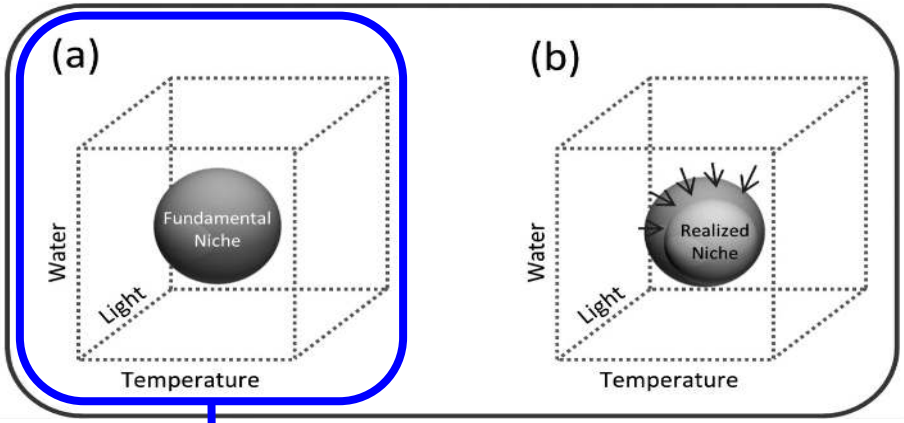


*Heteronotia* (EA6 lineage) presence/absence

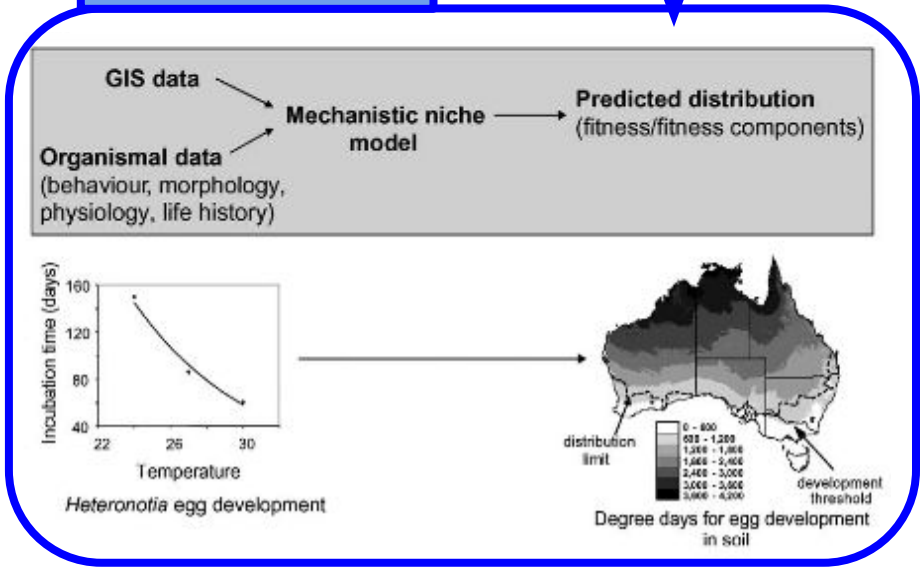


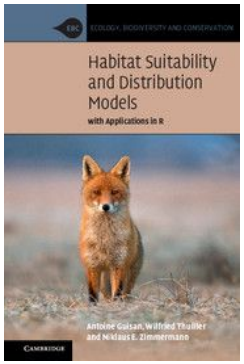
# Nicho fundamental

## Modelos mecanísticos




Mecanísticos




Guisan et al. (2017)

Como determinar o **nicho fundamental** de uma espécie?

# Como determinar o nicho fundamental

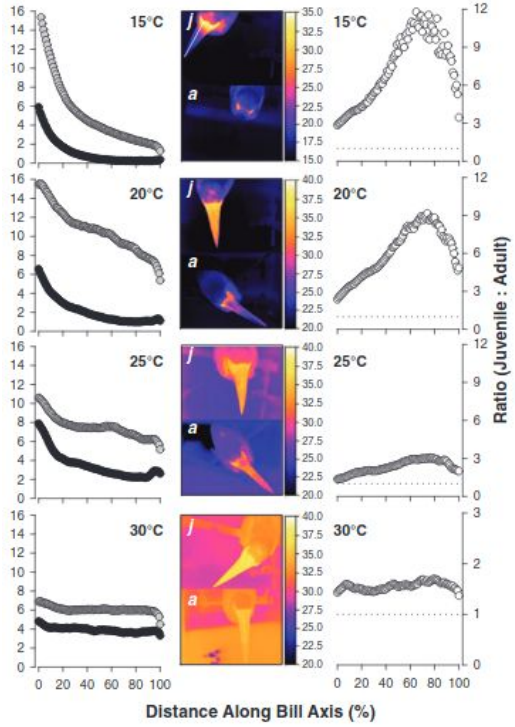
## Experimentos fisiológicos e traços funcionais

REPORT

### Heat Exchange from the Toucan Bill Reveals a Controllable Vascular Thermal Radiator

Glenn J. Tattersall[1,3], Denis V. Andrade[2,3], Augusto S. Abe[2,3]
+ See all authors and affiliations

*Science* 24 Jul 2009:
Vol. 325, Issue 5939, pp. 468-470
DOI: 10.1126/science.1175553

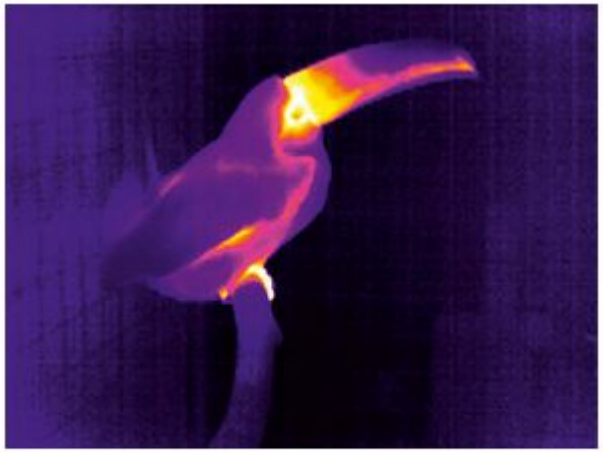



Imagem térmica mostra onde o calor se concentra *(em amarelo)*

THIAGO FILADELPHO

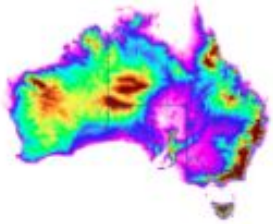
# Modelos mecanísticos

*Ecology Letters*, (2009) **12**: 334–350 doi: 10.1111/j.1461-0248.2008.01277.x

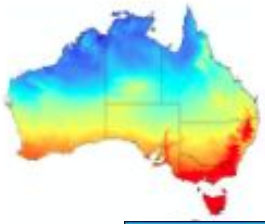
REVIEW AND SYNTHESIS

**Mechanistic niche modelling: combining physiological and spatial data to predict species'**

Michael Kearney[1]* and Warren Porter[2]

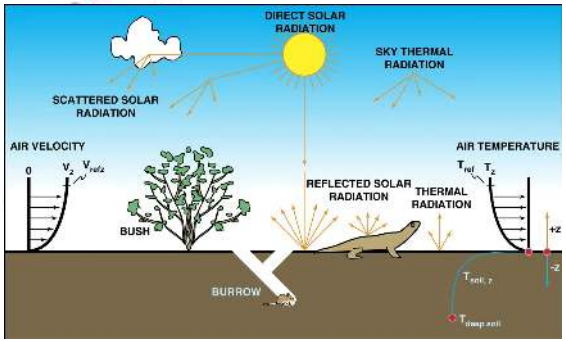


GIS Data In
climate
terrain
shading etc.



monthly/daily data

Microclimate Model




hourly microclimate per day/month

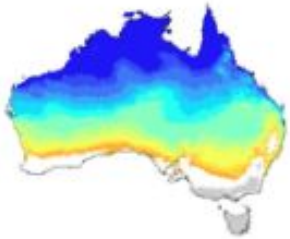
Organism/ Object Data
size/shape, reflectivity, diet, behaviour, performance curves etc.

Organism/Object Models

monthly/daily/hourly

GIS Data Out
survival, growth, reproduction, etc.

Potential Distribution



Kearney & Porter (2009)

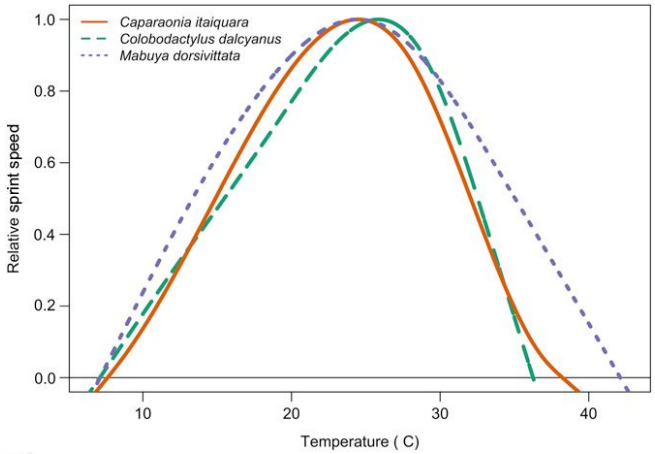
# Modelos mecanísticos

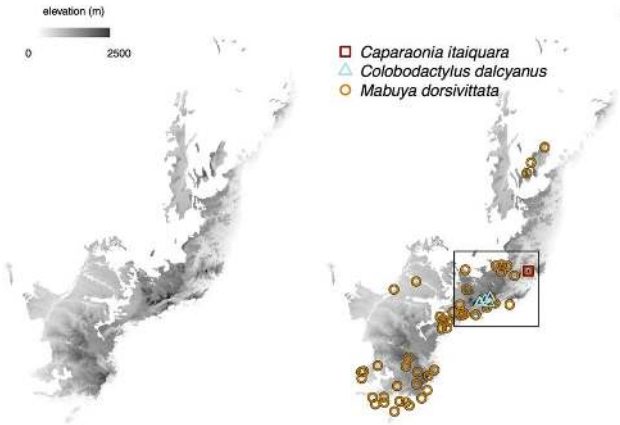
## Experimentos fisiológicos e traços funcionais

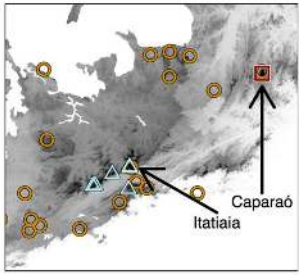
**Thermophysiology, microclimates, and species distributions of lizards in the mountains of the Brazilian Atlantic Forest**

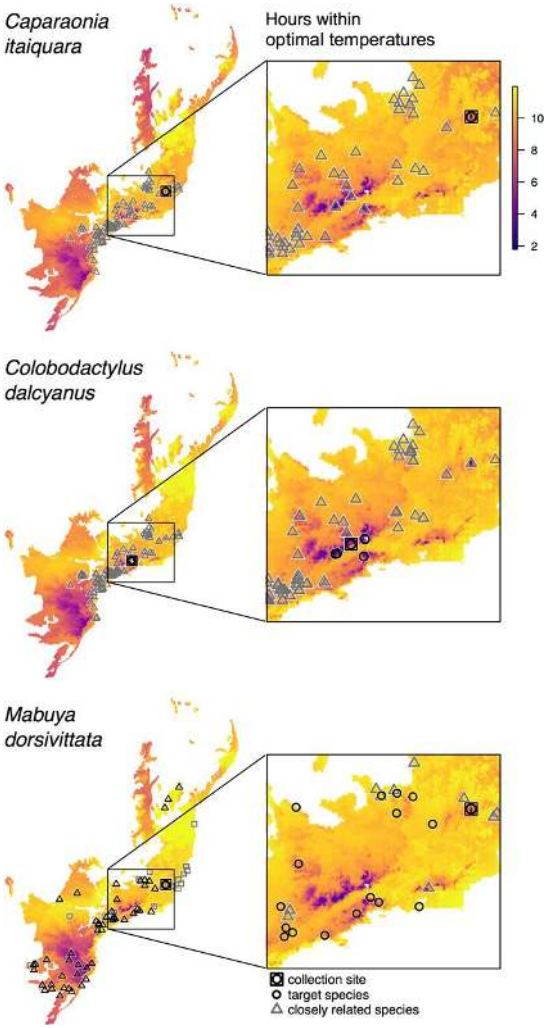
Maria L. Strangas, Carlos A. Navas, Miguel T. Rodrigues, Ana C. Carnaval


*Caparaonia itaiquara*



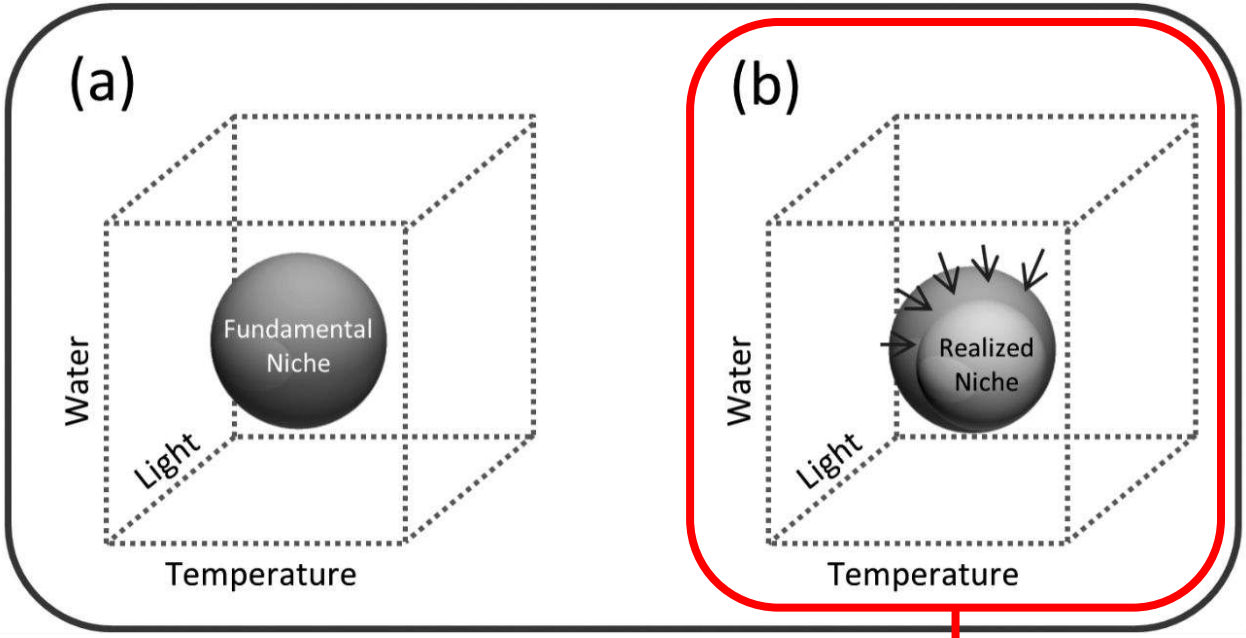



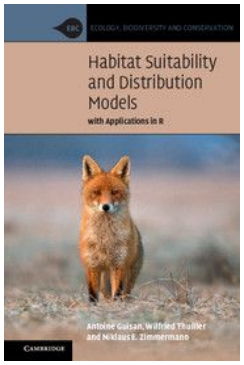



# Nicho realizado

## Modelos correlativos



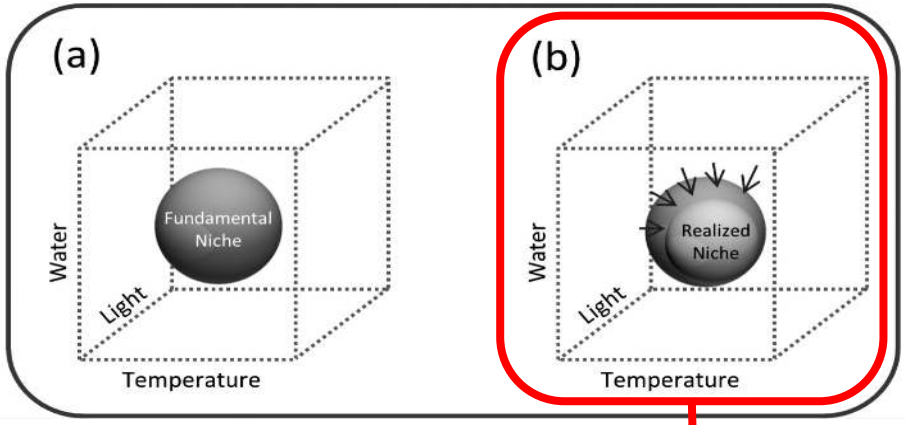

Correlativos

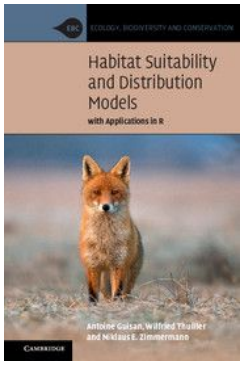



Guisan et al. (2017)

# Nicho realizado

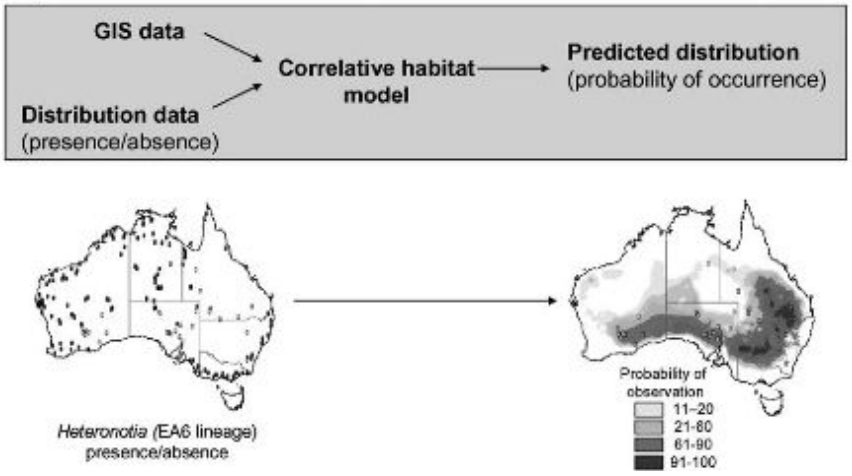
## Modelos correlativos




Guisan et al. (2017)

Correlativos

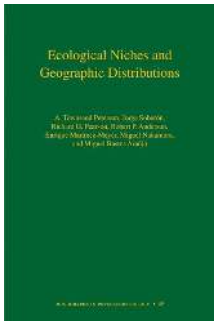


# Modelos correlativos

## Ocorrências

**Espaço geográfico (G)**

Jackson & Overpack (2000)



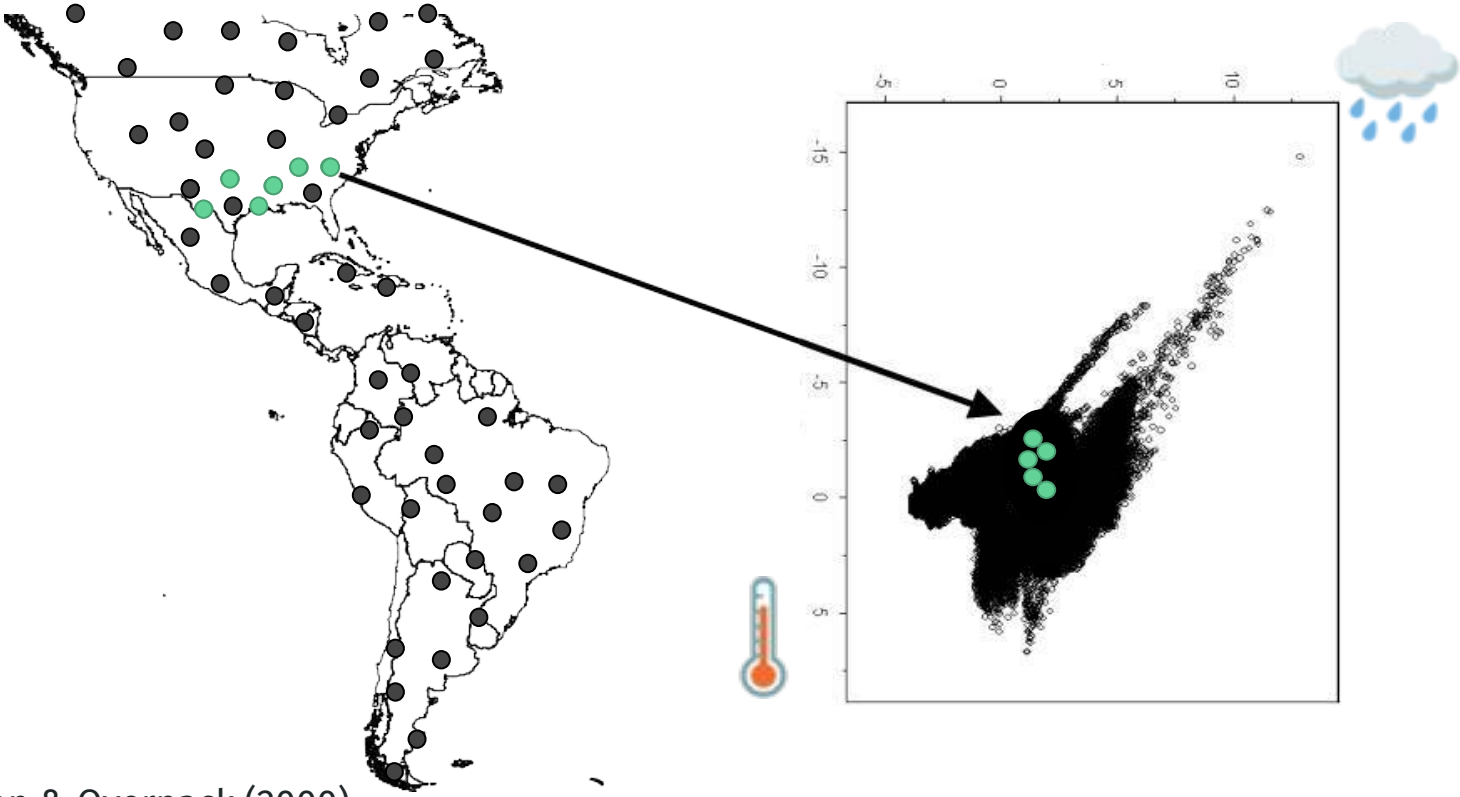

Peterson et al. (2011)

# Modelos correlativos

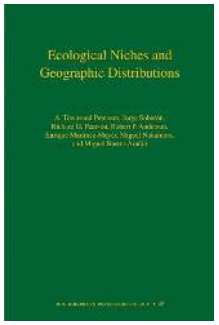
## Condições ambientais

**Espaço geográfico (G)**

**Espaço ambiental (E)**



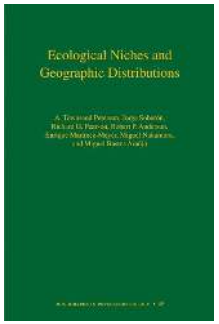
Jackson & Overpack (2000)



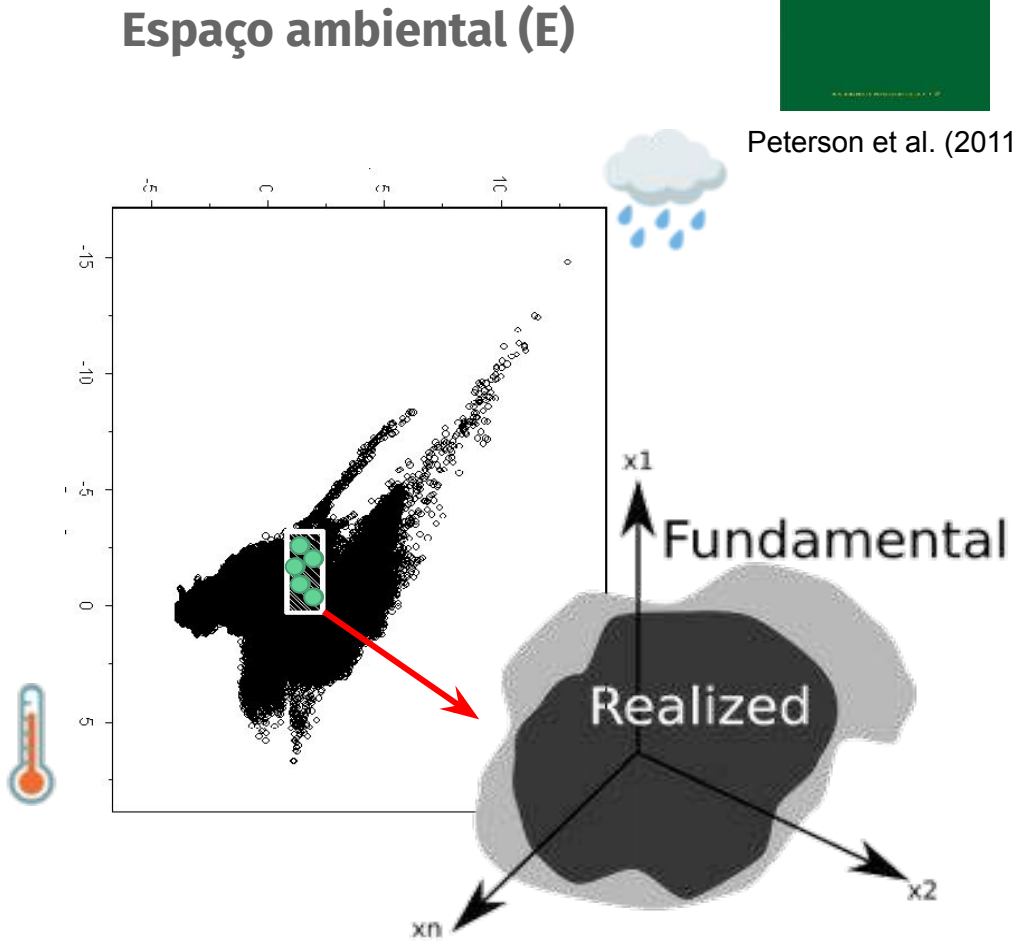

Peterson et al. (2011)

# Modelos correlativos

## Estimativa do nicho realizado



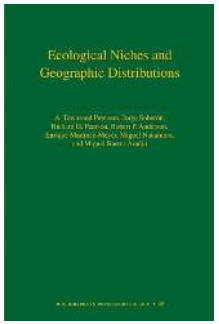

Peterson et al. (2011)




Jackson & Overpack (2000)

# Modelos correlativos

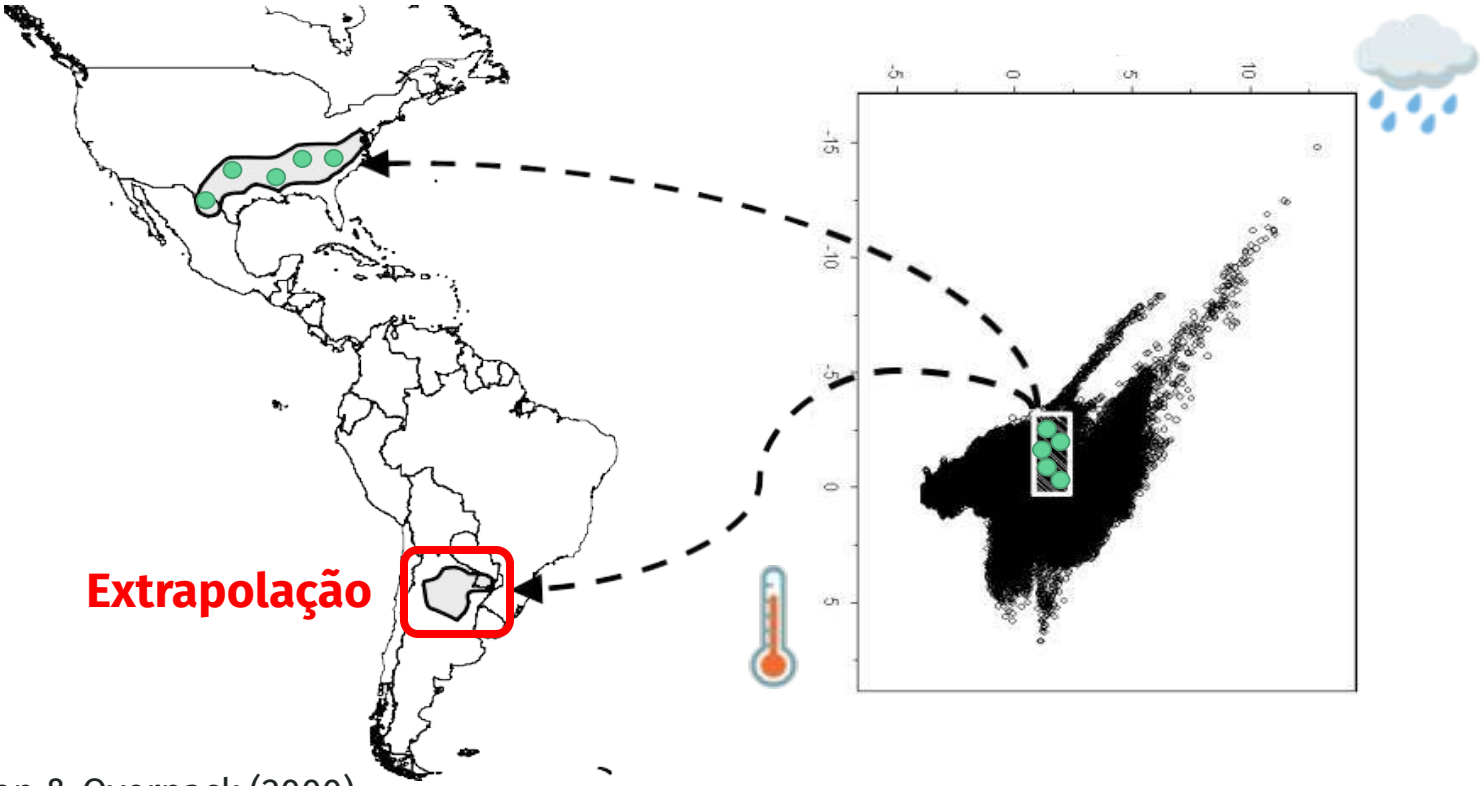
## Predição do nicho realizado estimado




Peterson et al. (2011)

**Espaço geográfico (G)**

**Espaço ambiental (E)**

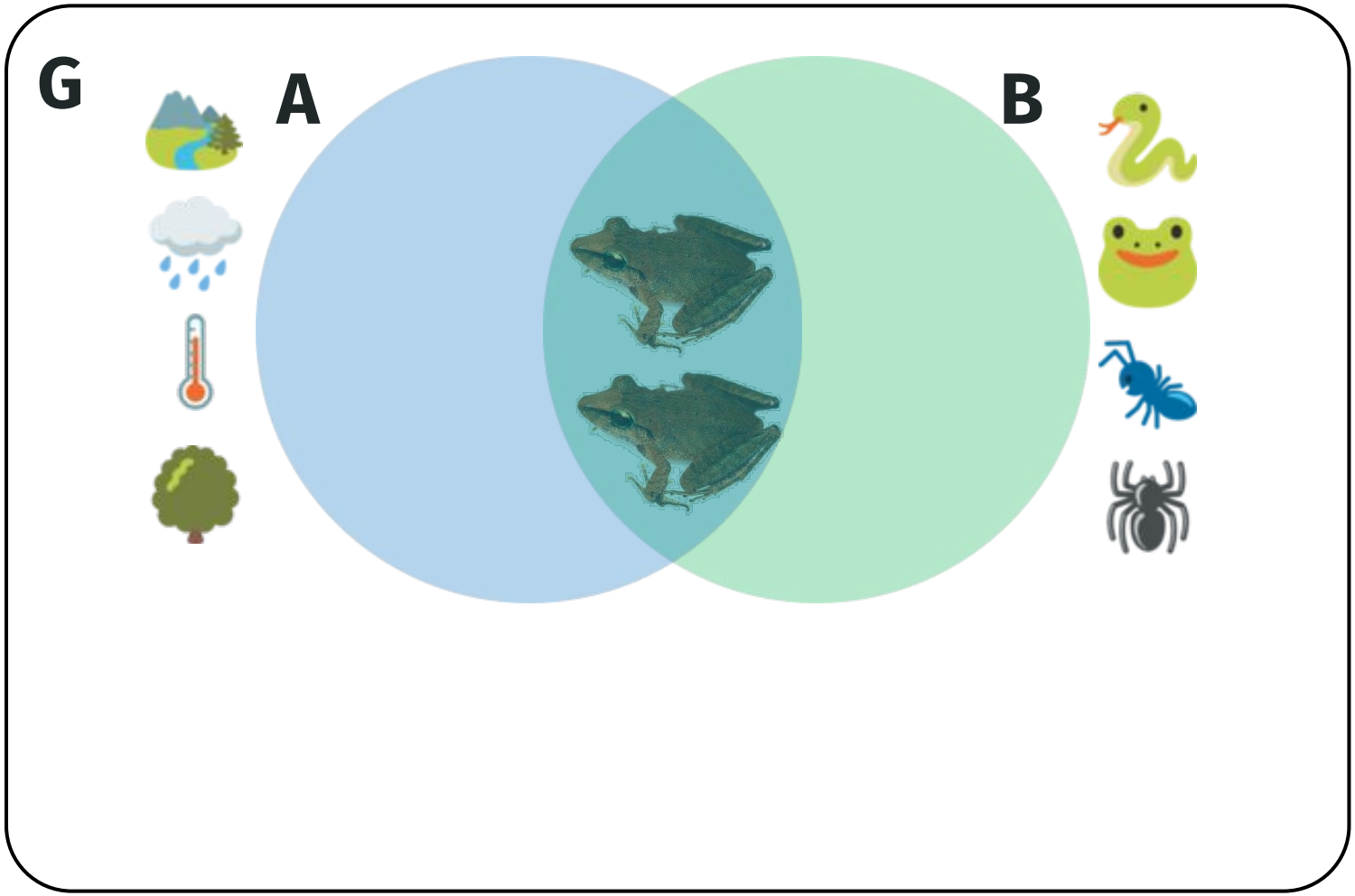


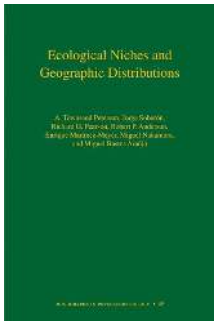

Jackson & Overpack (2000)

E como contornar essa **extrapolação**?

# O que determina a distribuição das espécies?

## Nicho Ecológico

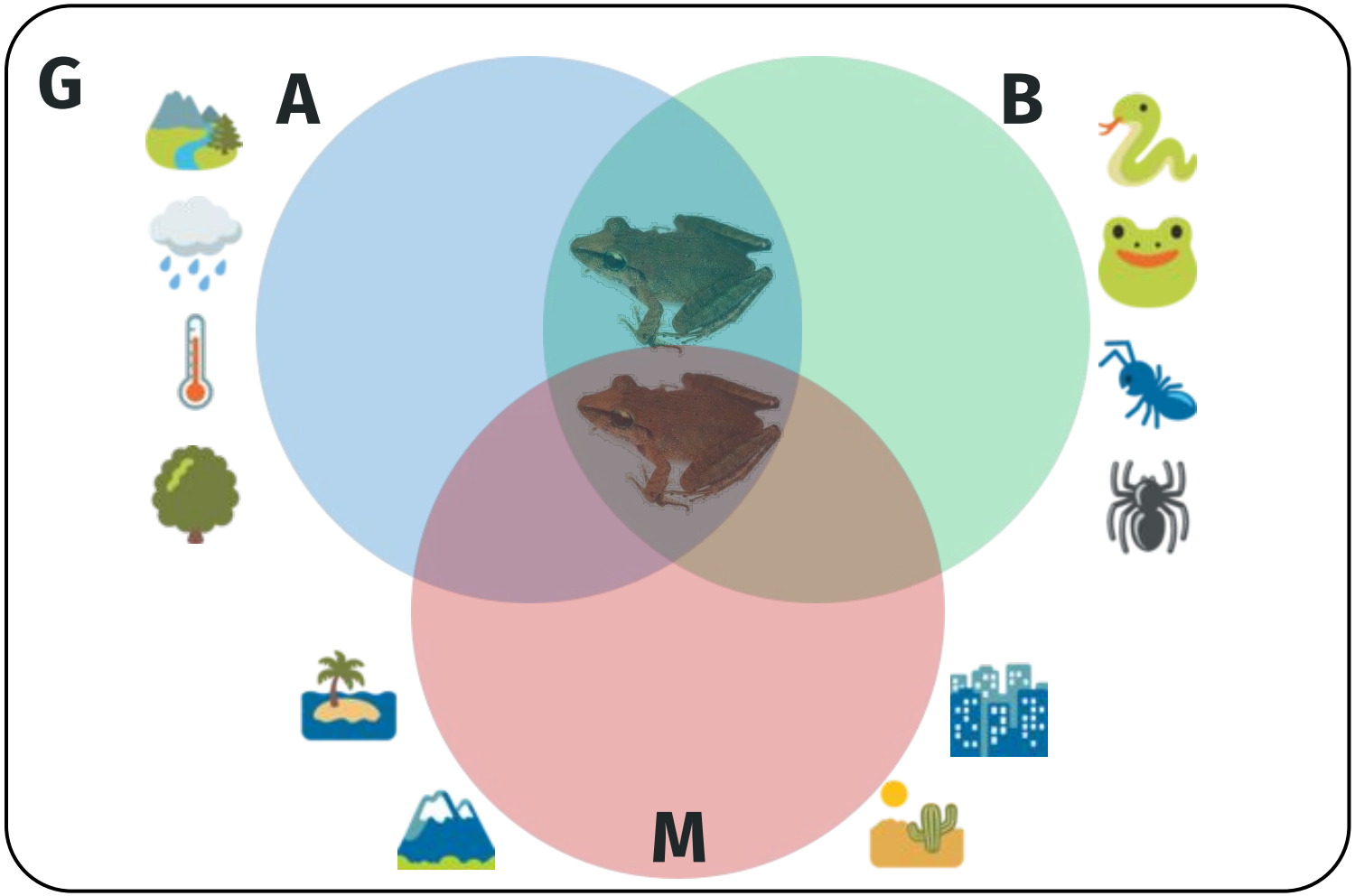


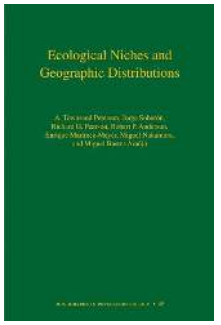




Peterson et al. (2011)

# O que determina a distribuição das espécies?

## Nicho Ecológico limitado pelo **movimento**

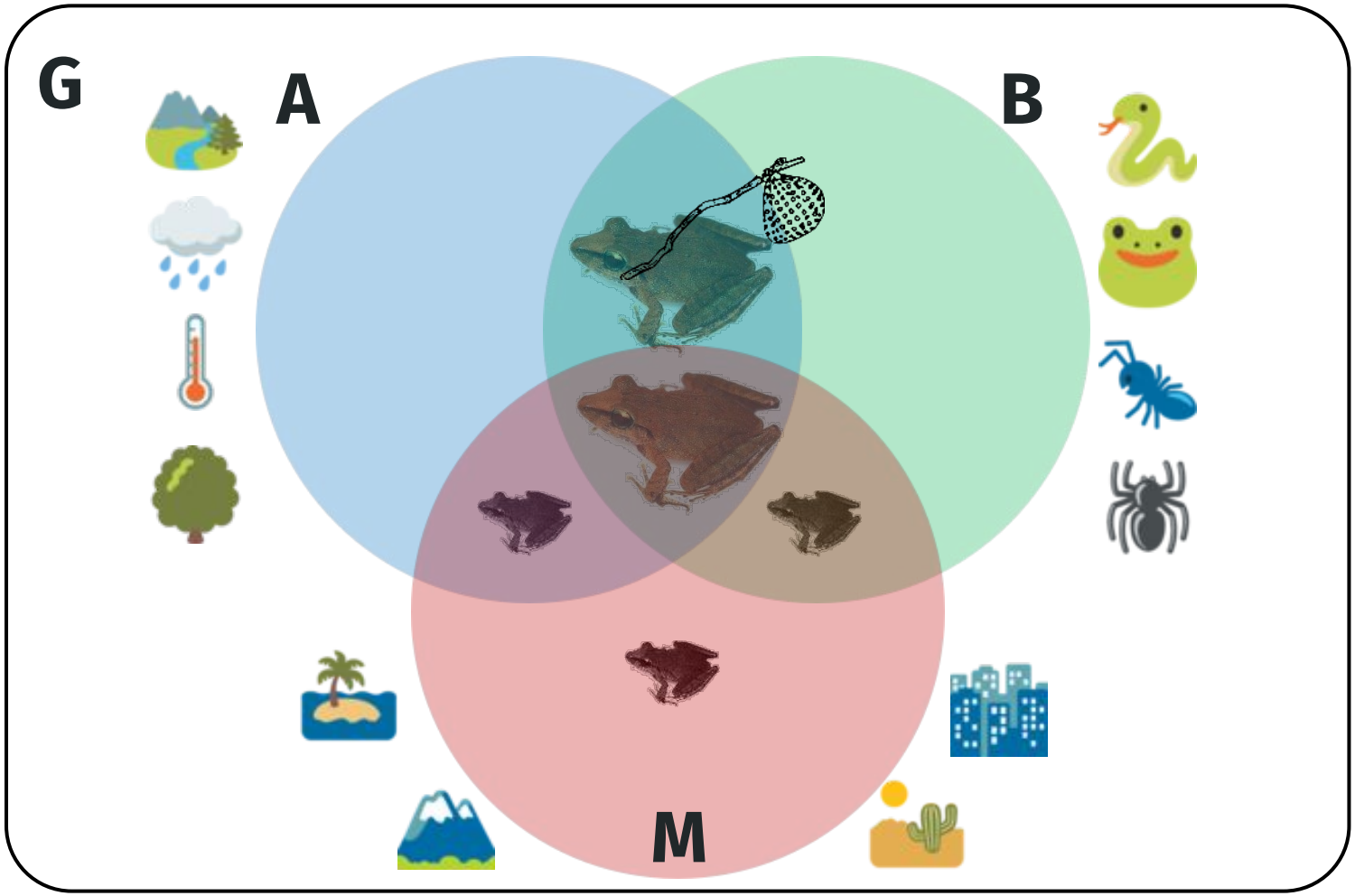


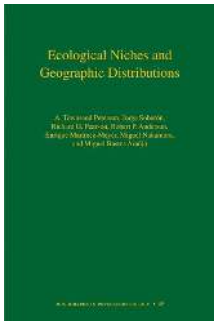




Peterson et al. (2011)

# O que determina a distribuição das espécies?

## Populações fonte e ralo (*source-sink*)




Peterson et al. (2011)

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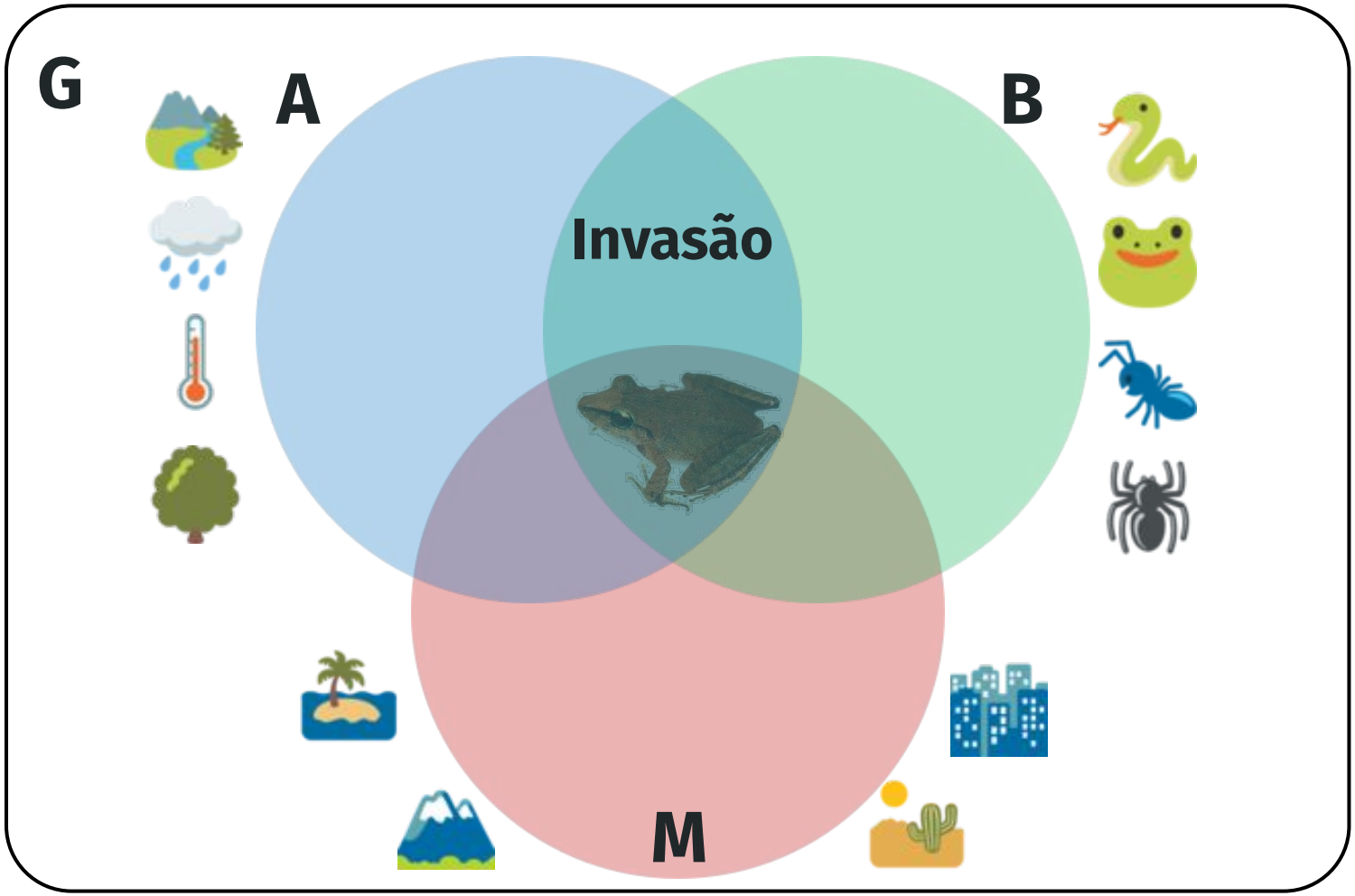


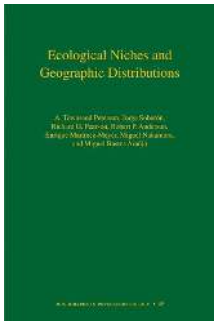


Peterson et al. (2011)

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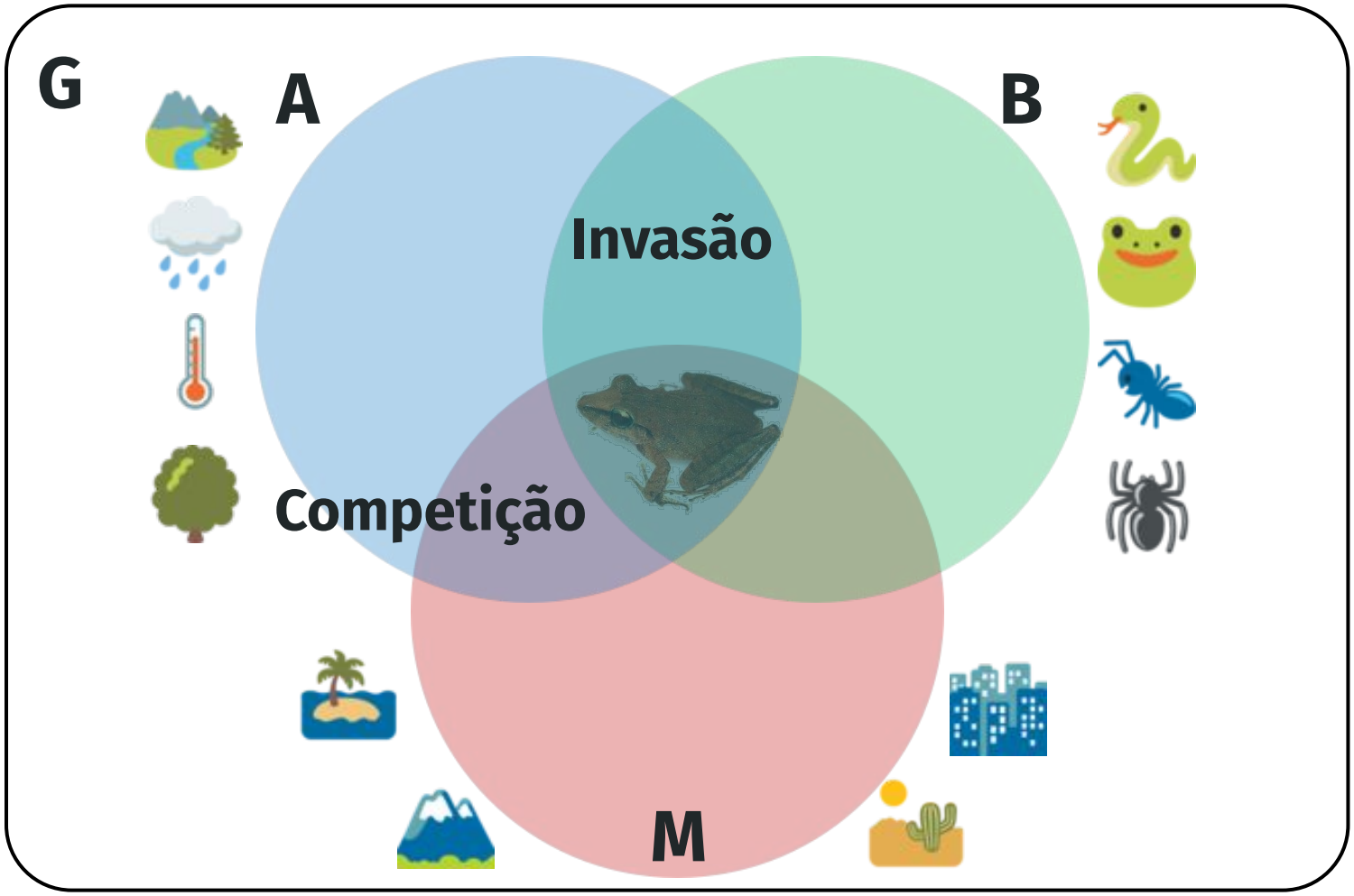


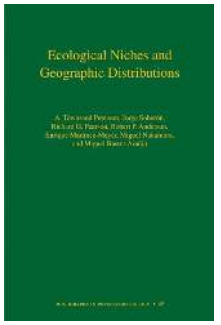


Peterson et al. (2011)

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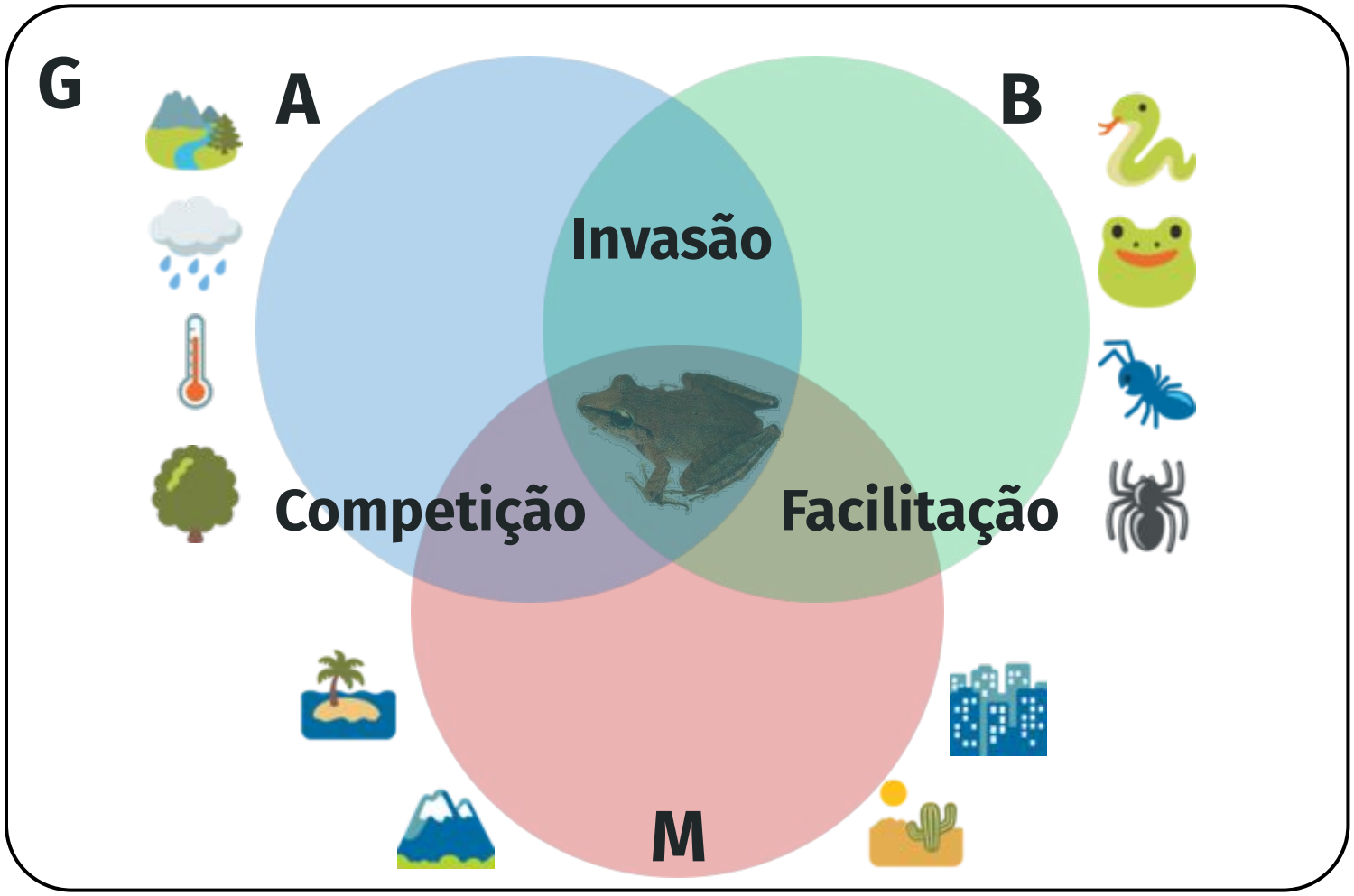


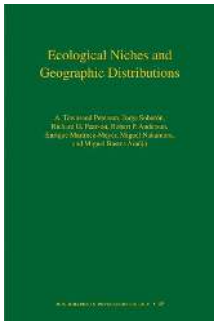


Peterson et al. (2011)

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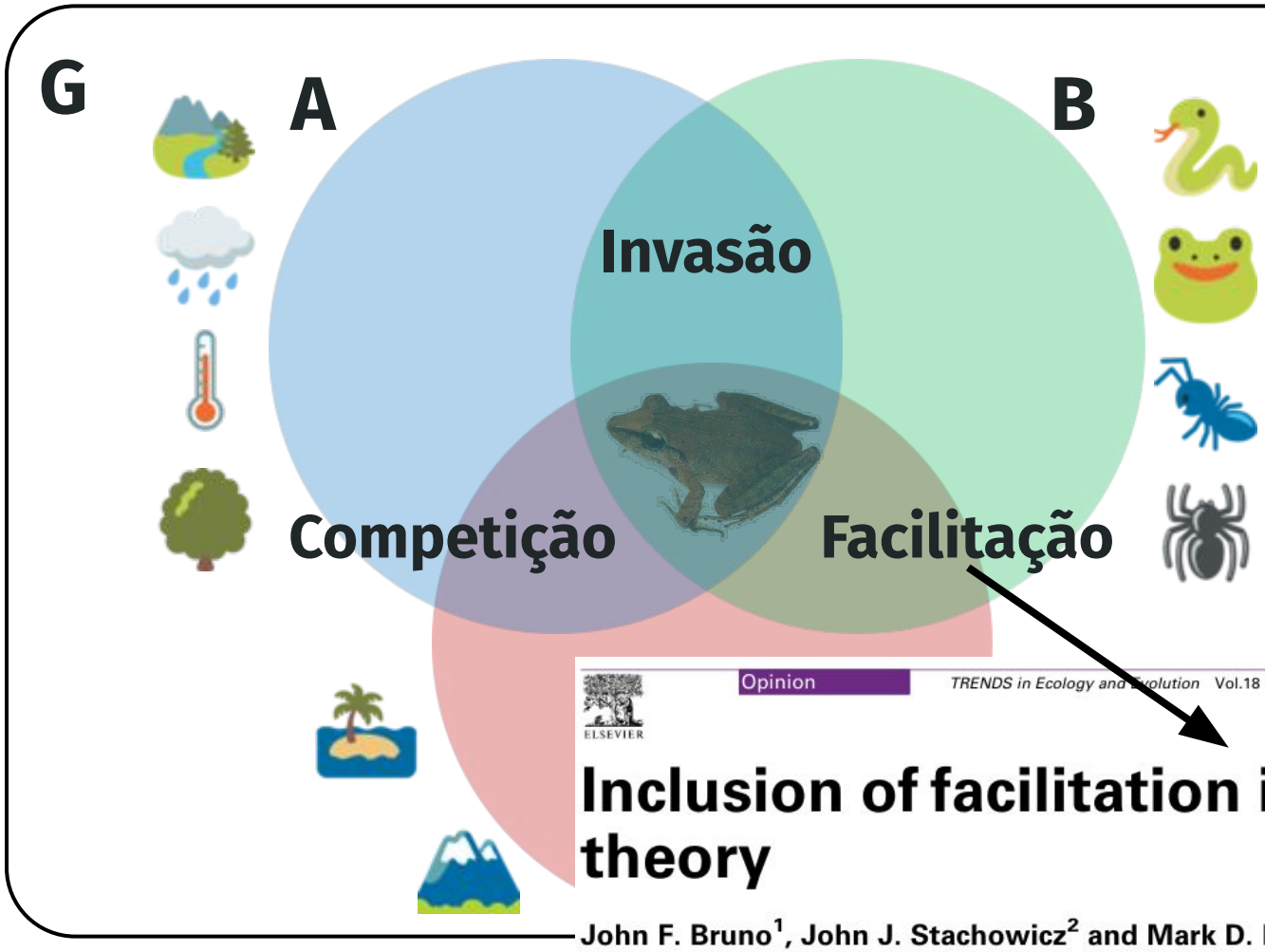
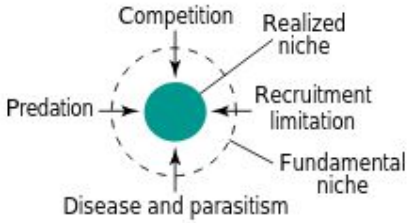
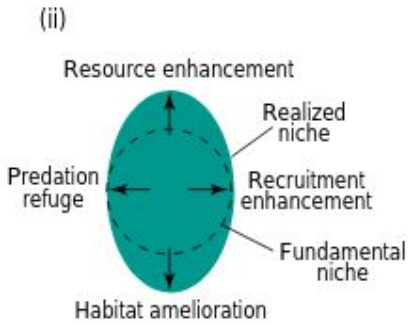


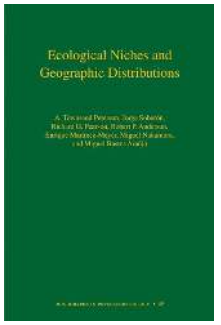

Opinion TRENDS in Ecology and Evolution Vol.18 No.3 March 2003 119

**Inclusion of facilitation into ecological theory**

John F. Bruno[1], John J. Stachowicz[2] and Mark D. Bertness[3]

# O que determina a distribuição das espécies?

## Populações fonte e ralo (*source-sink*)

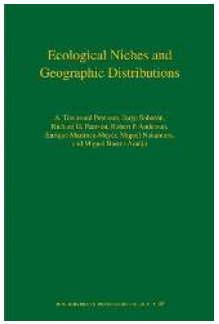




Peterson et al. (2011)

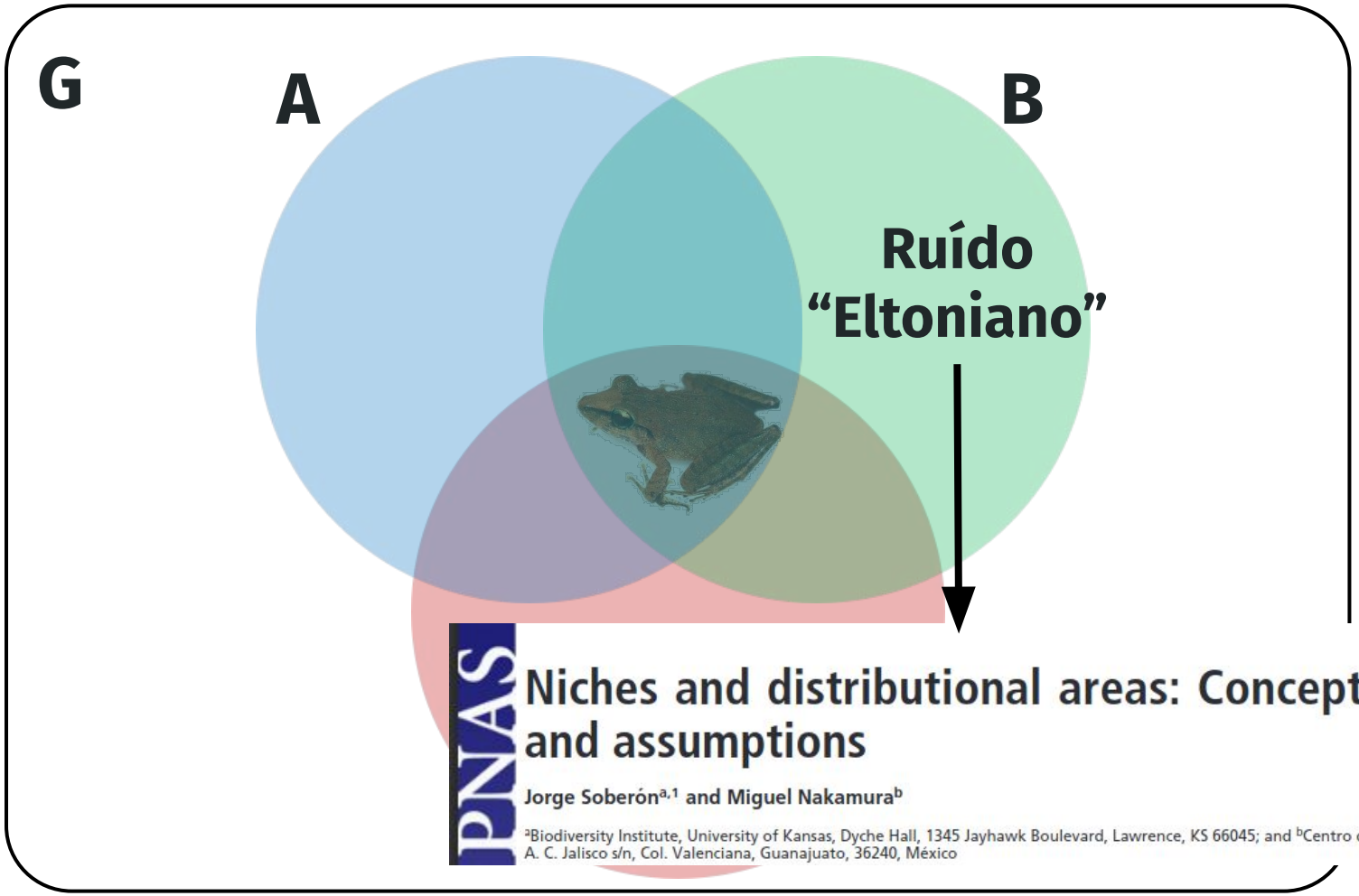
E as **interações bióticas**?

# O que determina a distribuição das espécies?

## Interações bióticas “ignoradas”




Peterson et al. (2011)




PNAS

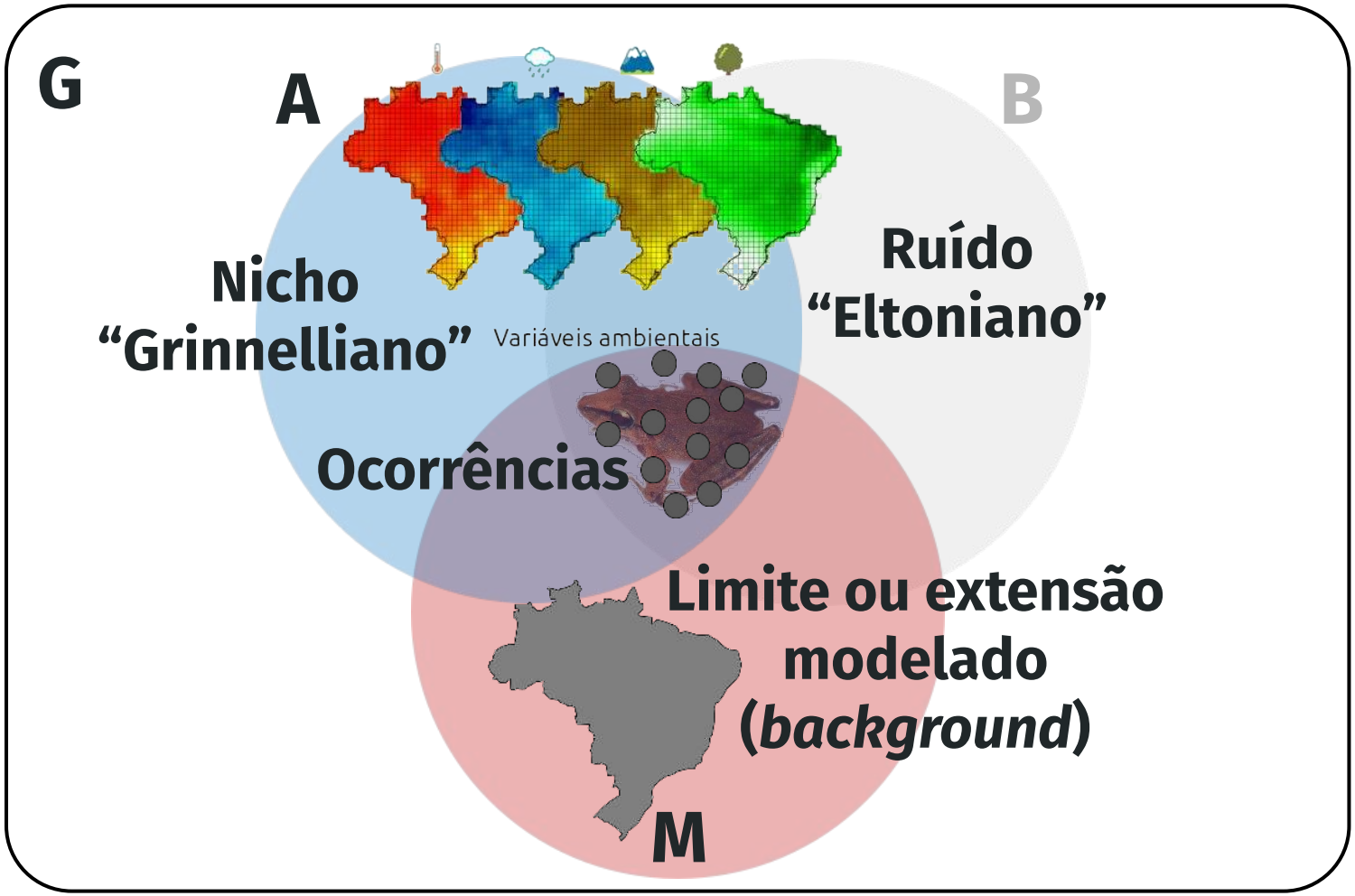
**Niches and distributional areas: Concepts, methods, and assumptions**

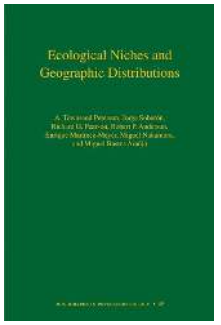
Jorge Soberón[a,1] and Miguel Nakamura[b]

[a]Biodiversity Institute, University of Kansas, Dyche Hall, 1345 Jayhawk Boulevard, Lawrence, KS 66045; and [b]Centro de Investigación en Matemáticas, A. C. Jalisco s/n, Col. Valenciana, Guanajuato, 36240, México

# O que determina a distribuição das espécies?

## Estimativa do nicho Grinnelliano realizado




Peterson et al. (2011)

# Área em desenvolvimento

## Como inserir as interações bióticas nos SDMs?

RESEARCH PAPER

WILEY Journal of Biogeography

**Using biotic interactions in broad-scale estimates of species' distributions**

Iulian Gherghel[1,2,3] | François Brischoux[4] | Monica Papeş[5]

BIOLOGICAL REVIEWS Cambridge Philosophical Society

Open Access

**The role of biotic interactions in shaping distributions and realised assemblages of species: implications for species distribution modelling**

Mary Susanne Wisz, Julien Pottier, W. Daniel Kissling, Loïc Pellissier, Jonathan Lenoir, Christian F. Damgaard, Carsten F. Dormann, Mads C. Forchhammer, John-Arvid Grytnes ... See all authors

Journal of Biogeography

Original Article | Full Access

**The importance of biotic interactions in species distribution models: a test of the Eltonian noise hypothesis using parrots**

Carlos B. de Araújo, Luiz Octavio Marcondes-Machado, Gabriel C. Costa

Ecology and Evolution Open Access

ORIGINAL RESEARCH | Open Access

**Effects of biotic interactions on modeled species' distribution can be masked by environmental gradients**

William Godsoe, Janet Franklin, F. Guillaume Blanchet

RESEARCH REVIEWS

WILEY Global Ecology and Biogeography

**Biotic interactions in species distribution modelling: 10 questions to guide interpretation and avoid false conclusions**

Carsten F. Dormann[1] | Maria Bobrowski[2] | D. Matthias Dehling[3] | David J. Harris[4] | Florian Hartig[1,5] | Heike Lischke[6] | Marco D. Moretti[7] | Jörn Pagel[8] | Stefan Pinkert[9] | Matthias Schleuning[10] | Susanne I. Schmidt[11] | Christine S. Sheppard[8] | Manuel J. Steinbauer[12,13] | Dirk Zeuss[14] | Casper Kraan[15,16]

**Biotic interactions and climate in species distribution modelling**

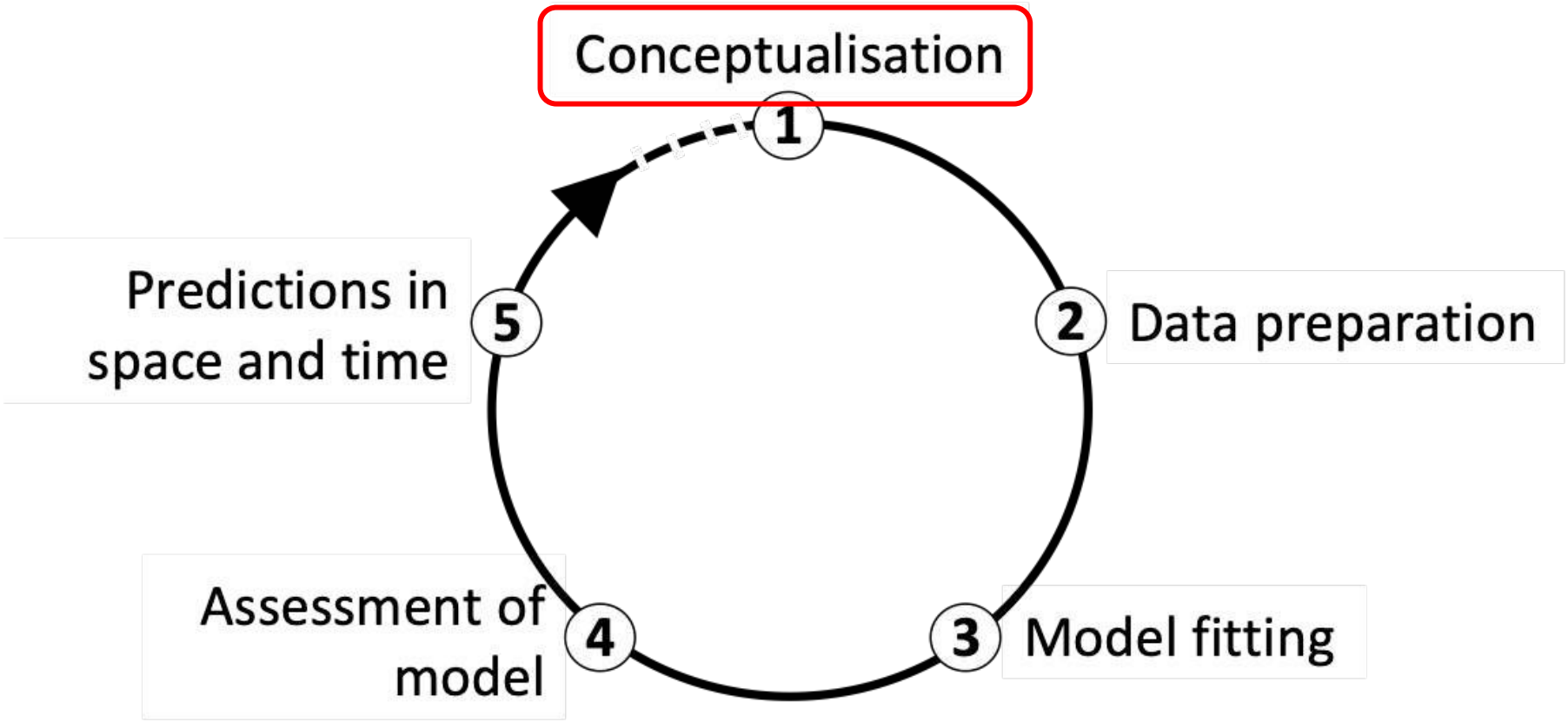
Daniel P. Bebber, Sarah J. Gurr

**doi:** https://doi.org/10.1101/520320

# 4. SDM passo a passo

# SDM passo a passo

## Estrutura dos SDMs



# Conceitualização

## Perguntas associadas à distribuição das espécies

Teoria -> Perguntas -> Hipóteses ->
Estatística (modelos) -> Respostas

# Conceitualização

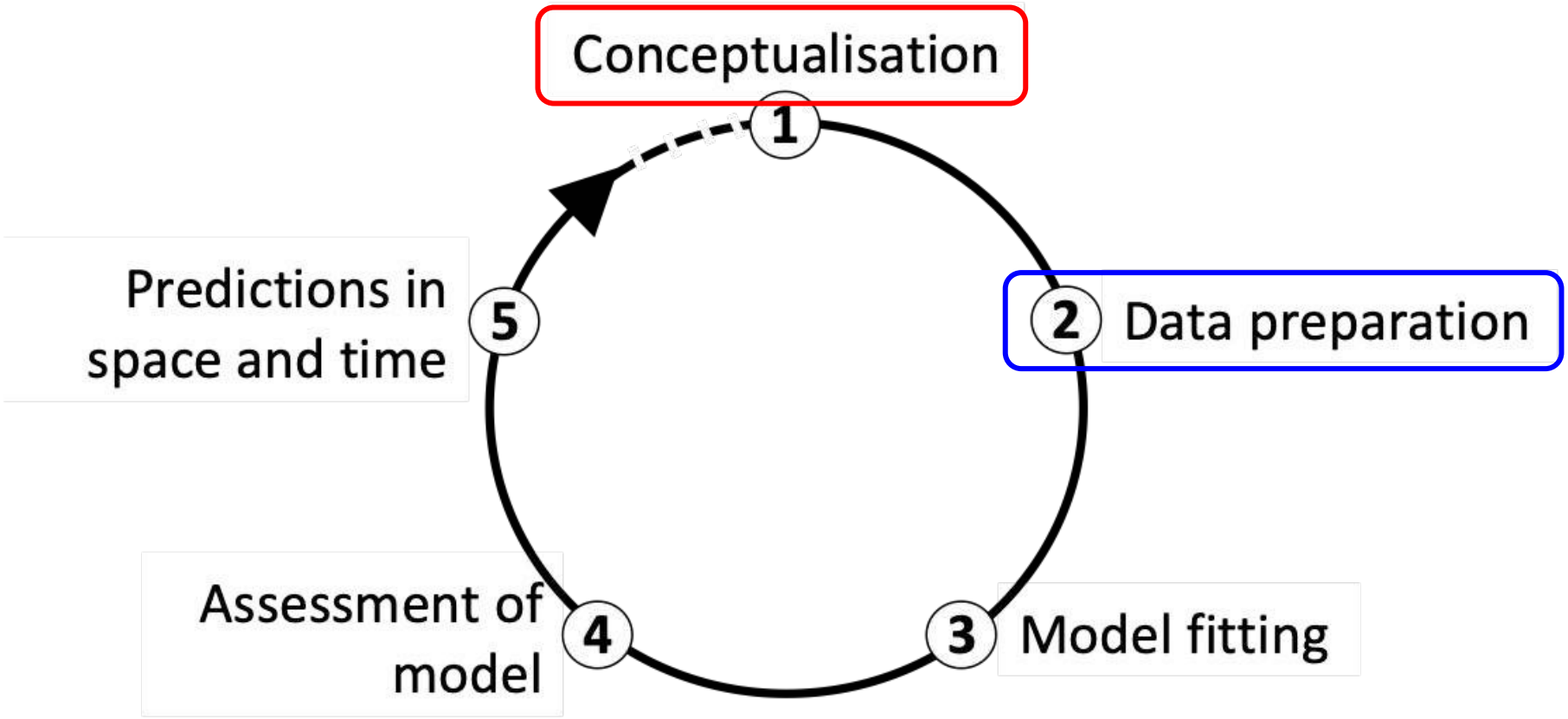
## Perguntas associadas à distribuição das espécies

Teoria -> Perguntas -> Hipóteses ->
Estatística (modelos) -> Respostas

1. Padrões de diversidade
2. Mudanças climáticas (futuro)
3. Mudanças climáticas (passado)
4. Invasão de espécies
5. Transmissão de doenças
6. Interações entre espécies
7. Processos de diversificação
8. Dispersão de espécies
9. Processos de extinção
10. Conservação-evolução do nicho
11. Testar hipóteses filogeográficas
12. Estabelecer refúgios climáticos
13. Estabelecer hotspots
14. Estabelecer áreas protegidas
15. Eficiência das áreas protegidas

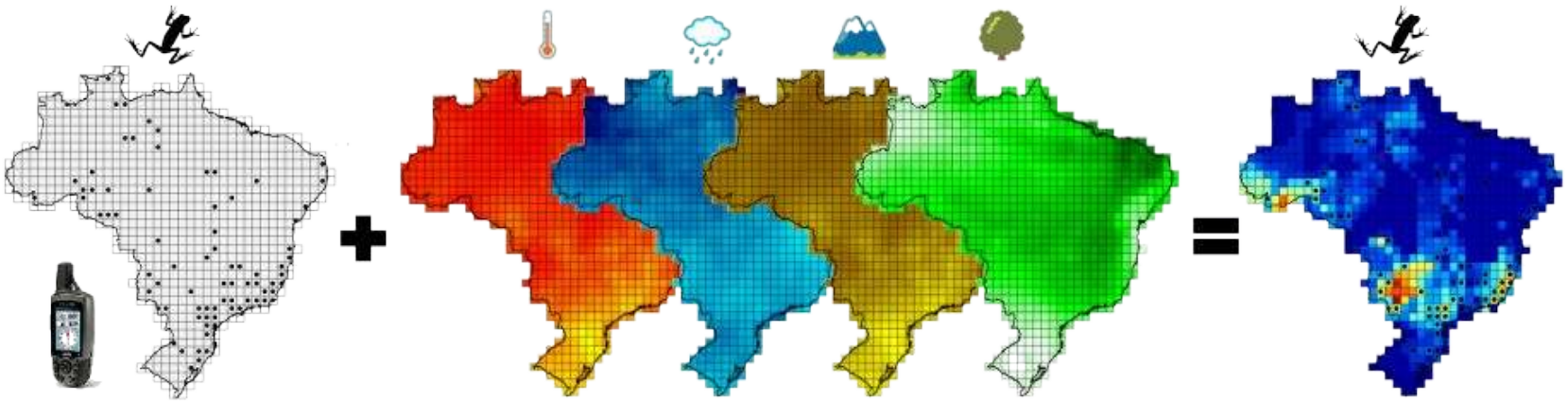
# SDM passo a passo

## Estrutura dos SDMs



# Modelos de Distribuição de Espécies (SDMs)

## Preparação dos dados



"Ocorrências"

| species | lon | lat |
|---|---|---|
| sp1 | -40.2 | -23.4 |
| sp1 | -38.8 | -20.3 |
| sp1 | -43.3 | -19.9 |

Variáveis ambientais

| variaveis |
|---|
| temperatura |
| precipitação |
| relevo |

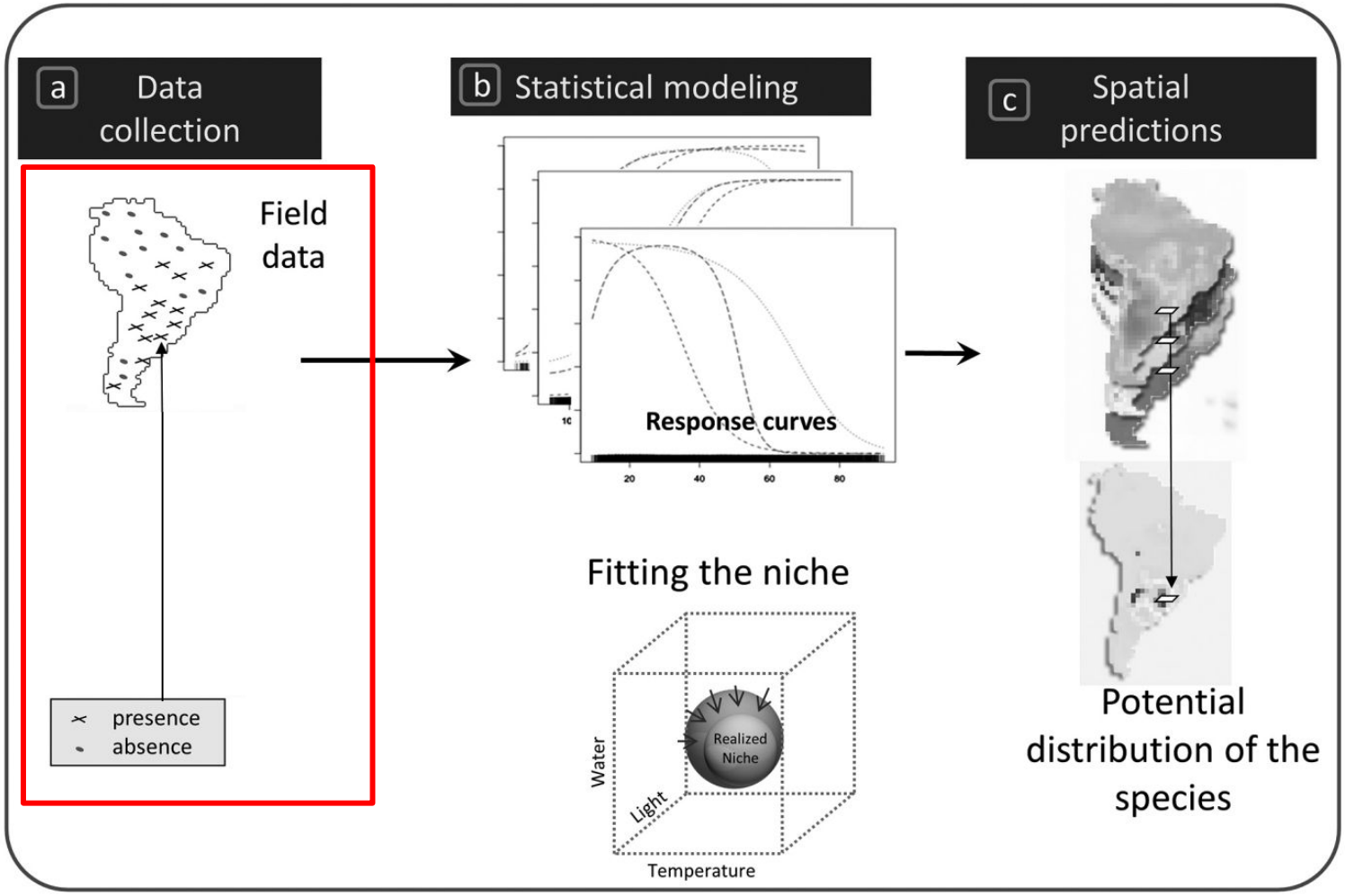
Adequabilidade

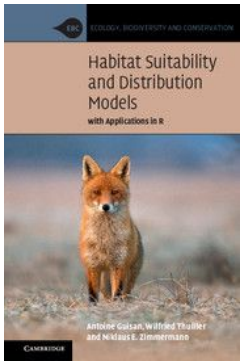
| valores |
|---|
| 0 |
| até |
| 1 |

# 5. Dados de entrada: ocorrências e variáveis

# Ocorrências

## Visão geral




Guisan et al. (2017)

# Ocorrências

## Fontes

1. Coletas em campo

# Ocorrências

## Fontes

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2. Literatura (artigos, data papers, ...)

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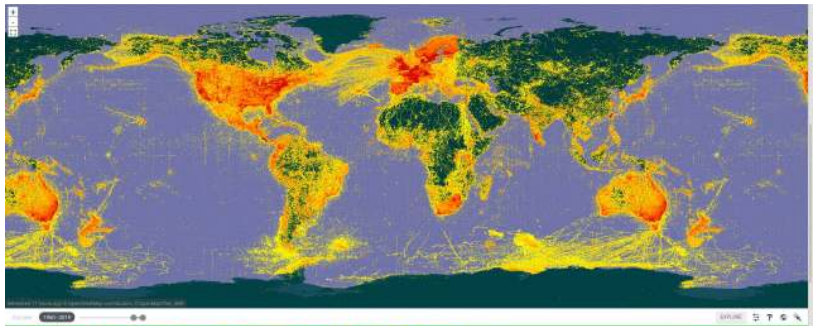
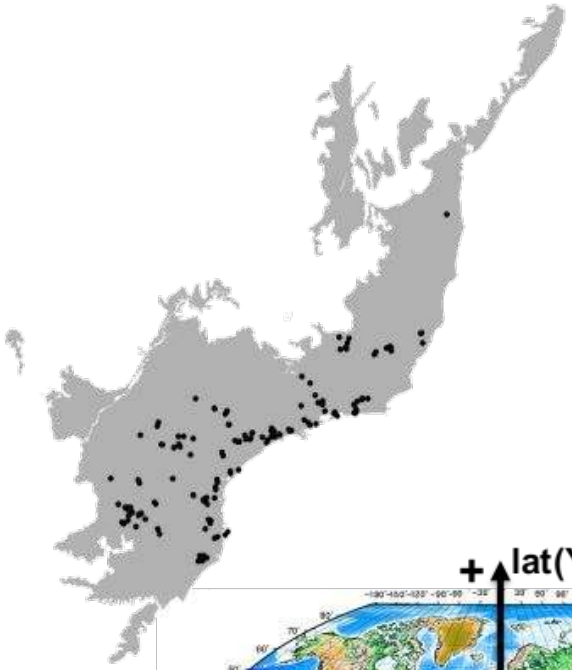
5. Banco de dados (GBIF, SpeciesLink, ...)

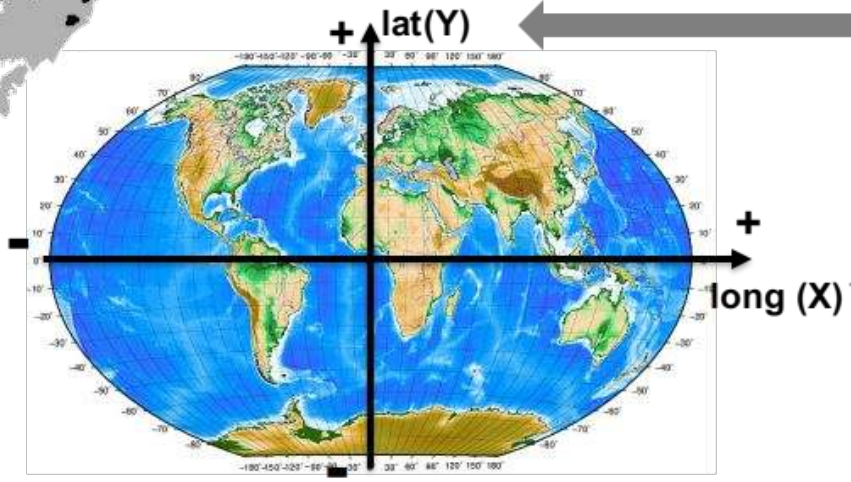



# Ocorrências

## Formato



| sp | long | lat |
|---|---|---|
| vitreorana_uranoscopa | -52.8300 | -26.4400 |
| vitreorana_uranoscopa | -52.6836 | -27.1253 |
| vitreorana_uranoscopa | -52.5569 | -26.5642 |
| vitreorana_uranoscopa | -52.4500 | -26.5667 |
| vitreorana_uranoscopa | -52.4489 | -27.0689 |
| vitreorana_uranoscopa | -52.4147 | -26.8667 |



# Ocorrências

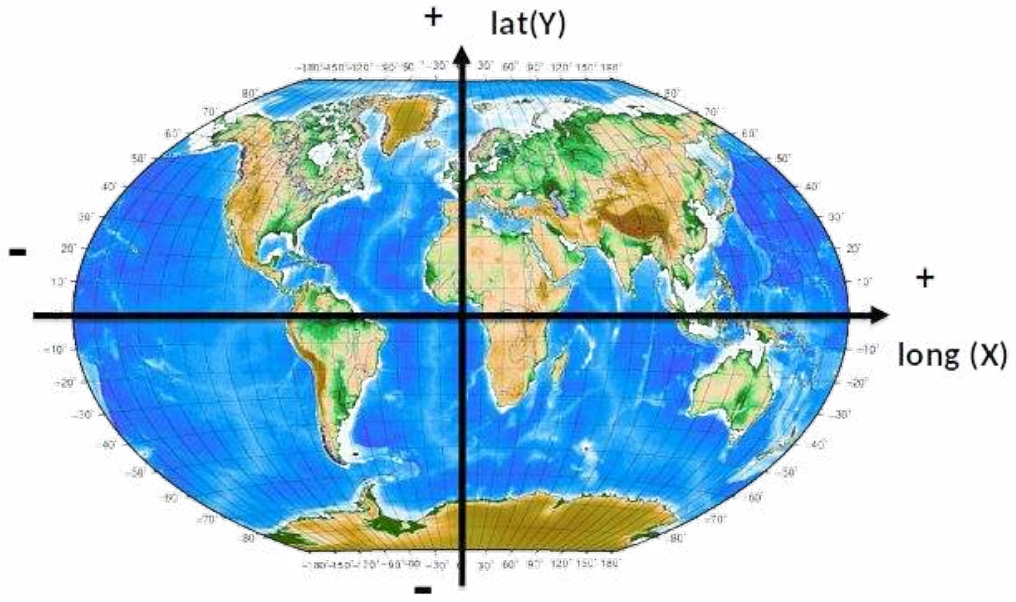
## Pressupostos

# Ocorrências

## Sistemas referência de coordenadas (SRC)

Geográficas (graus)

1. <u>Graus, minutos e segundos</u>
   Longitude: 42°42’42”O
   Latitude: 23°23’23”S



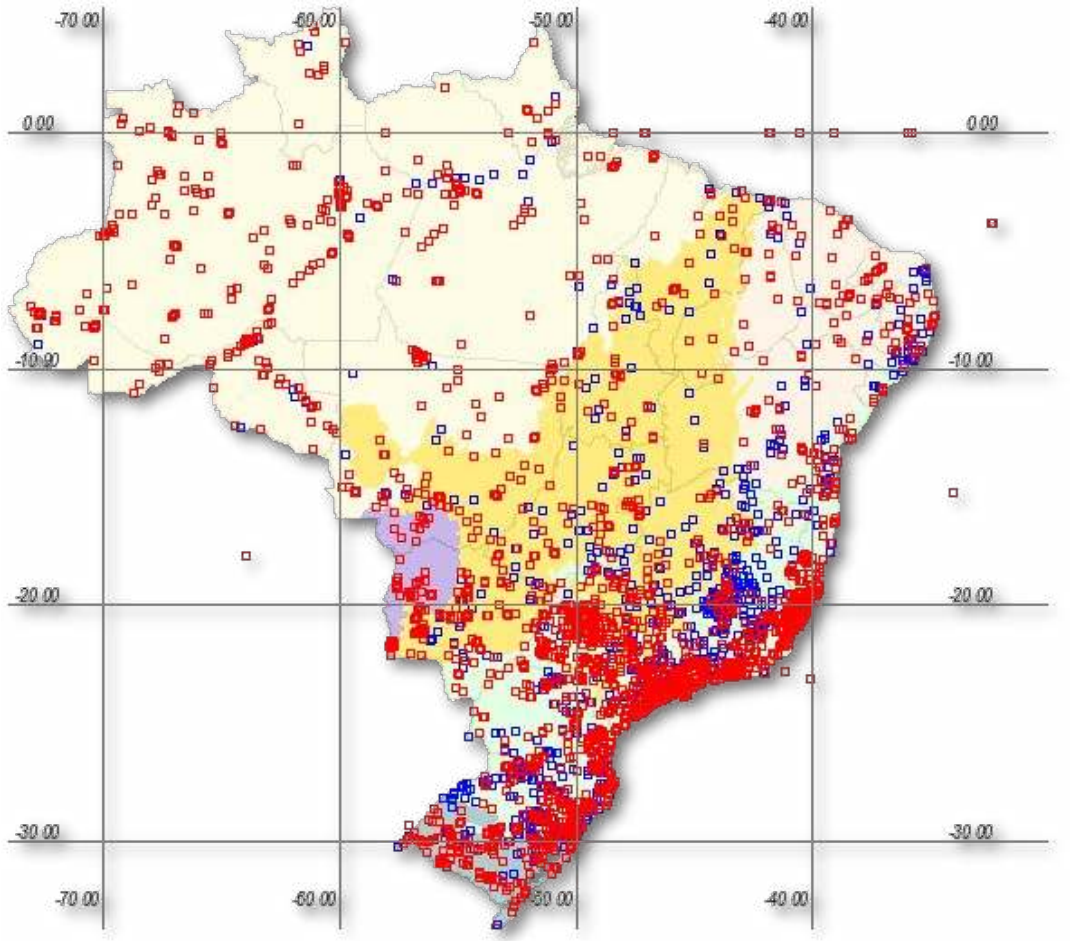

2. <u>Graus decimais</u>
   Longitude: -42.71167
   Latitude: -23.38972

   Converção: 23 + (23/60) + (23/3600)

# Desafios:
# Viés de amostragem

# Ocorrências

## Viés de amostragem

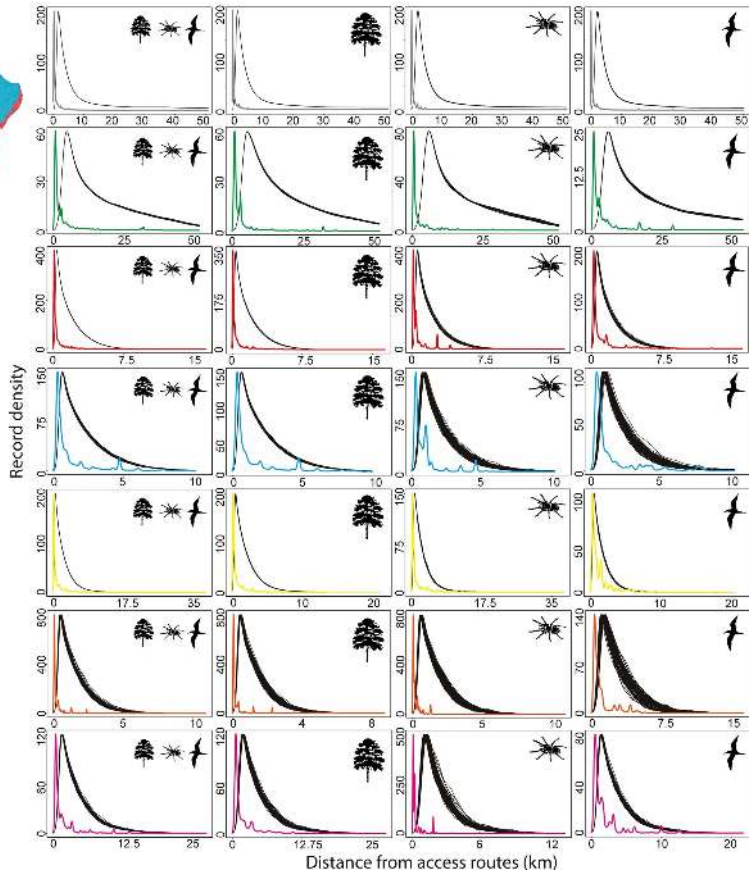



*Boana faber*

speciesLink

# Ocorrências

## Viés de amostragem

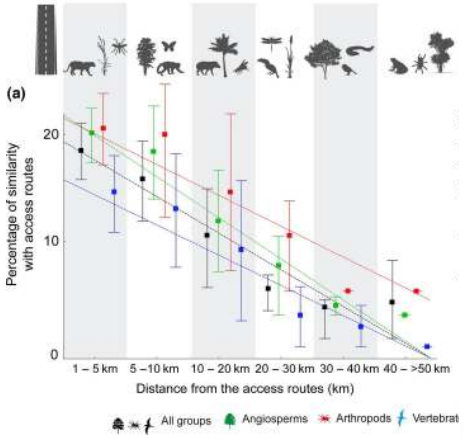



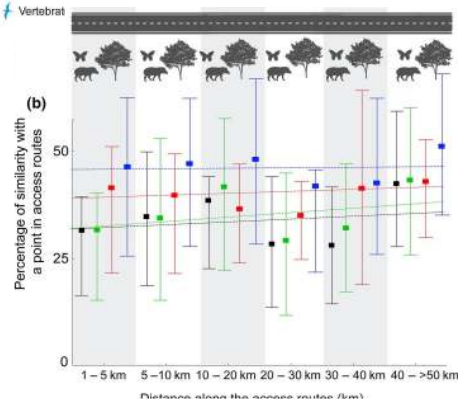

*Diversity and Distributions*, (Diversity Distrib.) (2016) **22**, 1232–1244

BIODIVERSITY RESEARCH

**The strong influence of collection bias on biodiversity knowledge shortfalls of Brazilian terrestrial biodiversity**

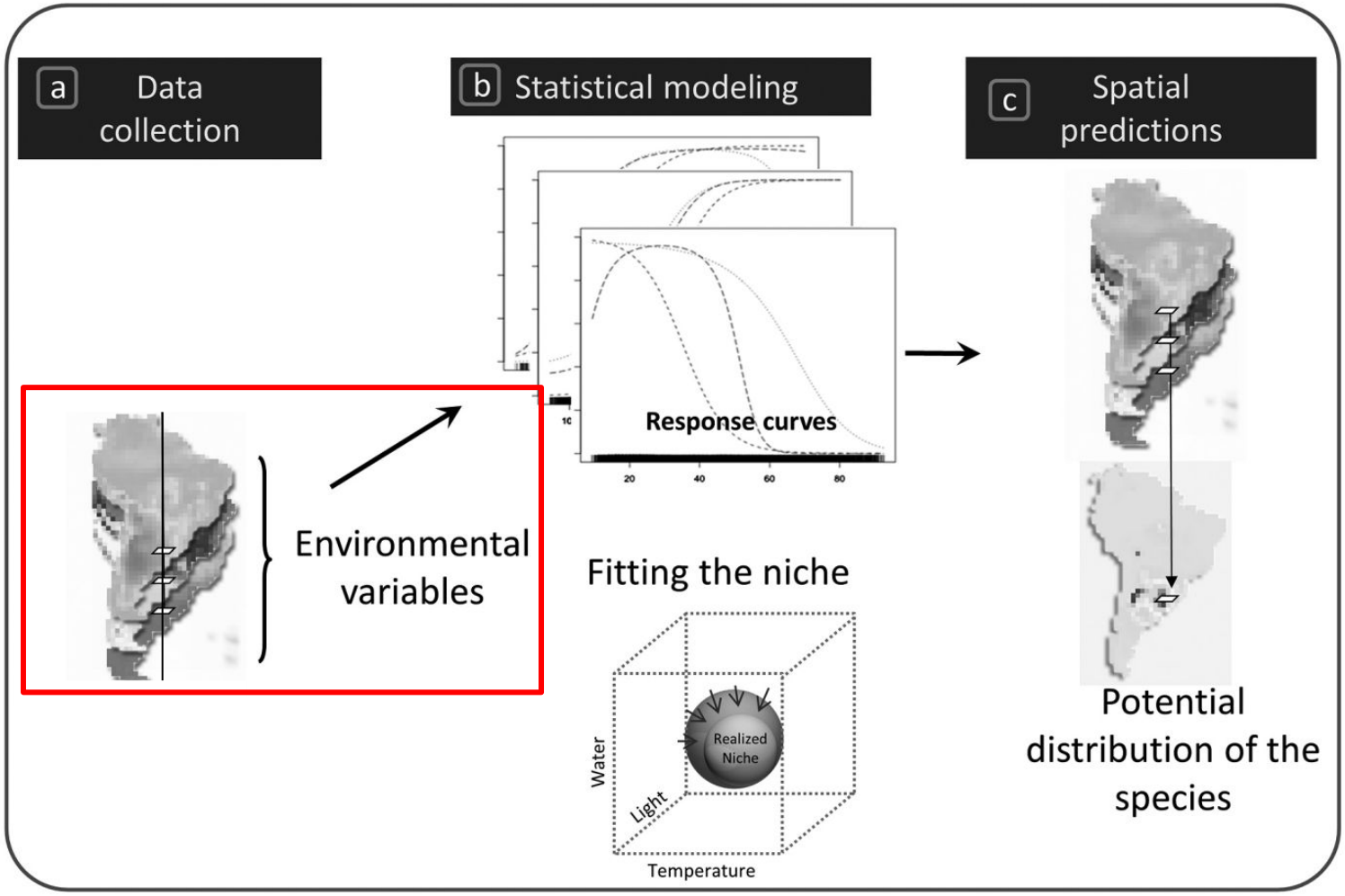
Ubirajara Oliveira[1,2*], Adriano Pereira Paglia[3], Antonio D. Brescovit[4], Claudio J. B. de Carvalho[5], Daniel Paiva Silva[6], Daniella T. Rezende[7], Felipe Sá Fortes Leite[8], João Aguiar Nogueira Batista[9], João Paulo Peixoto Pena Barbosa[4], João Renato Stehmann[9], John S. Ascher[10], Marcelo Ferreira de Vasconcelos[11,12], Paulo De Marco Jr[13], Peter Löwenberg-Neto[14], Priscila Guimarães Dias[15], Viviane Gianluppi Ferro[15] and Adalberto J. Santos[2]

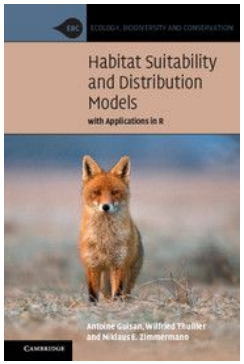


# Variáveis ambientais

## Visão geral

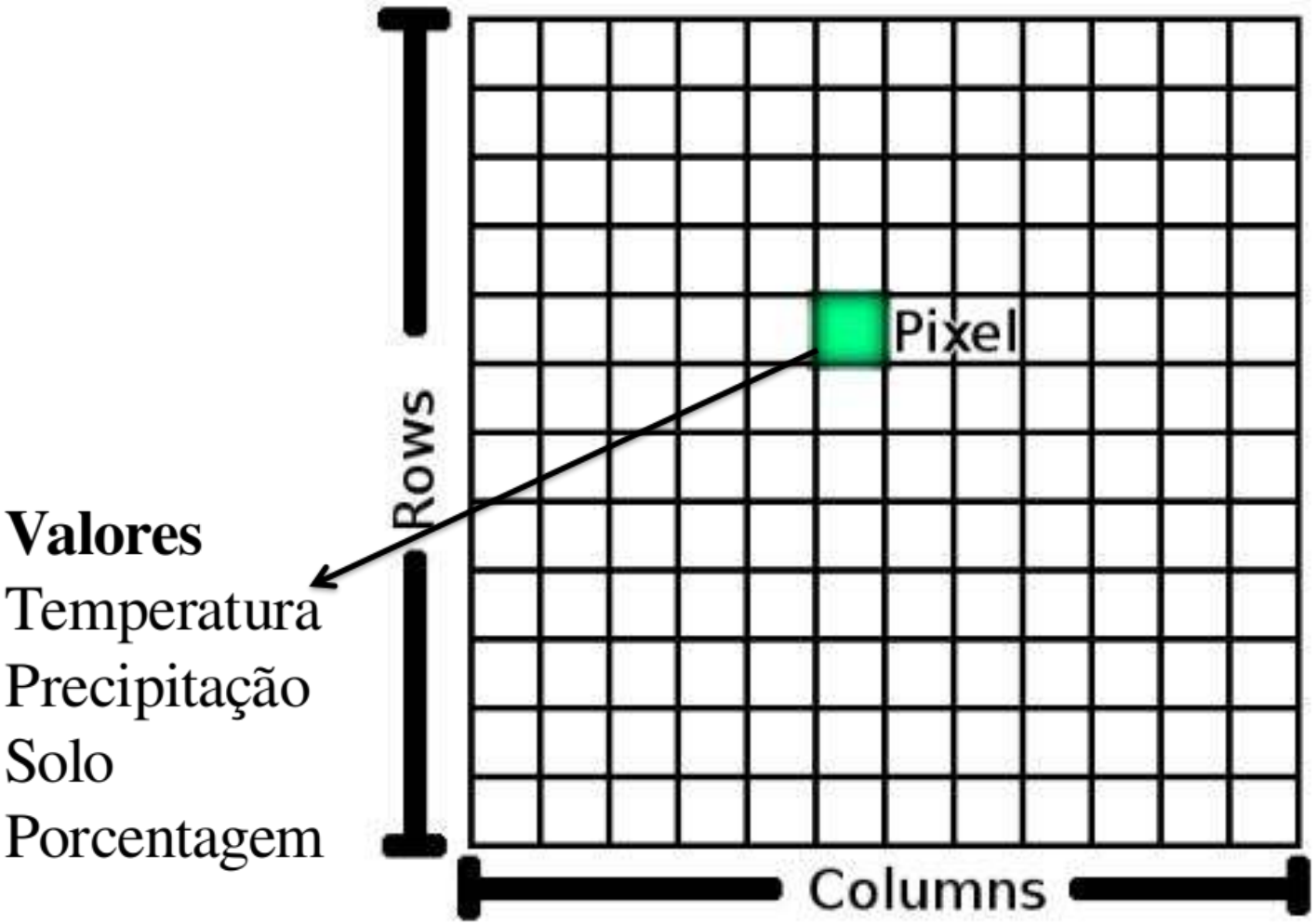



Guisan et al. (2017)

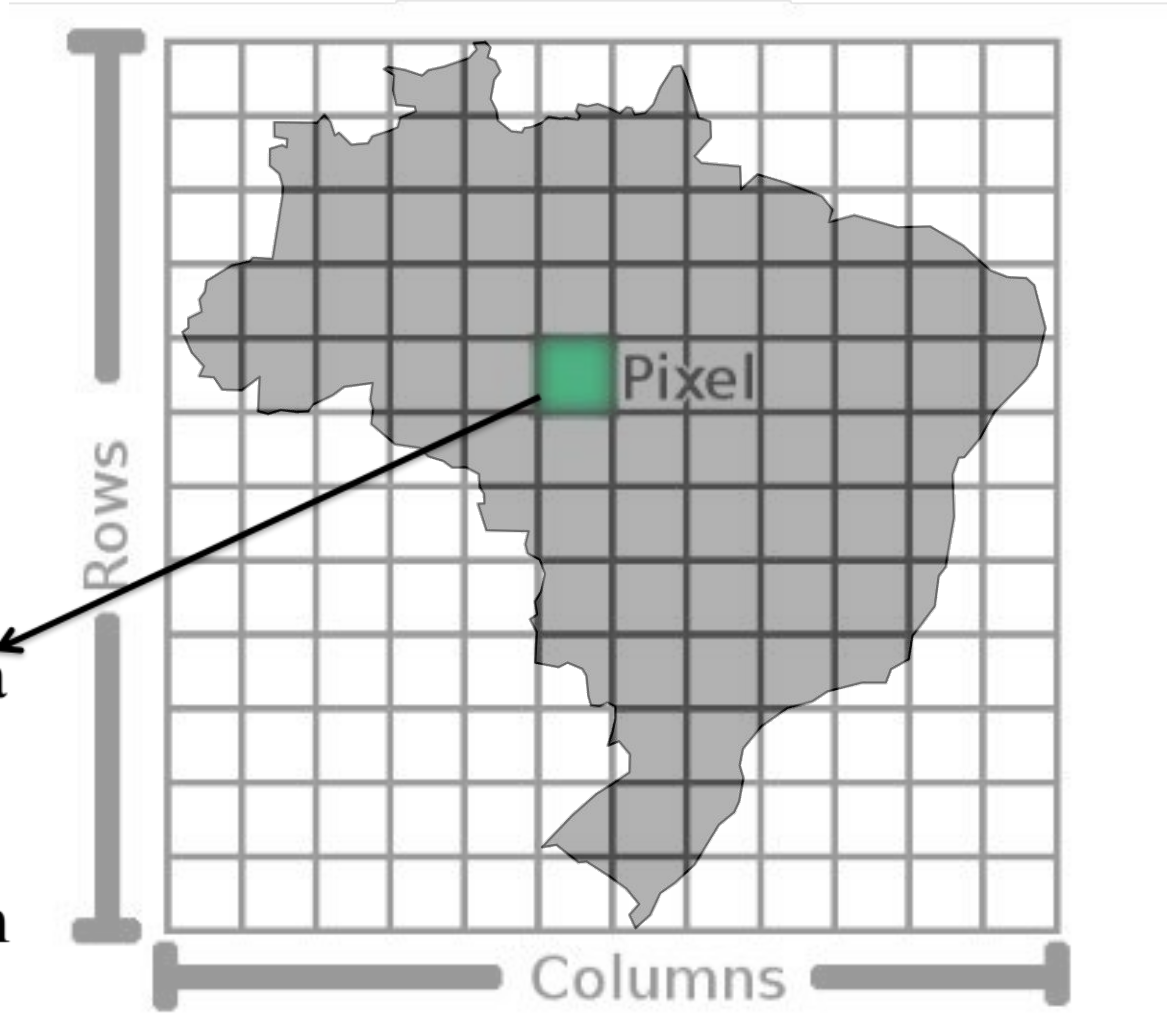
# Variáveis ambientais

## Raster - Extensão e resolução



# Variáveis ambientais

## Raster - Extensão e resolução

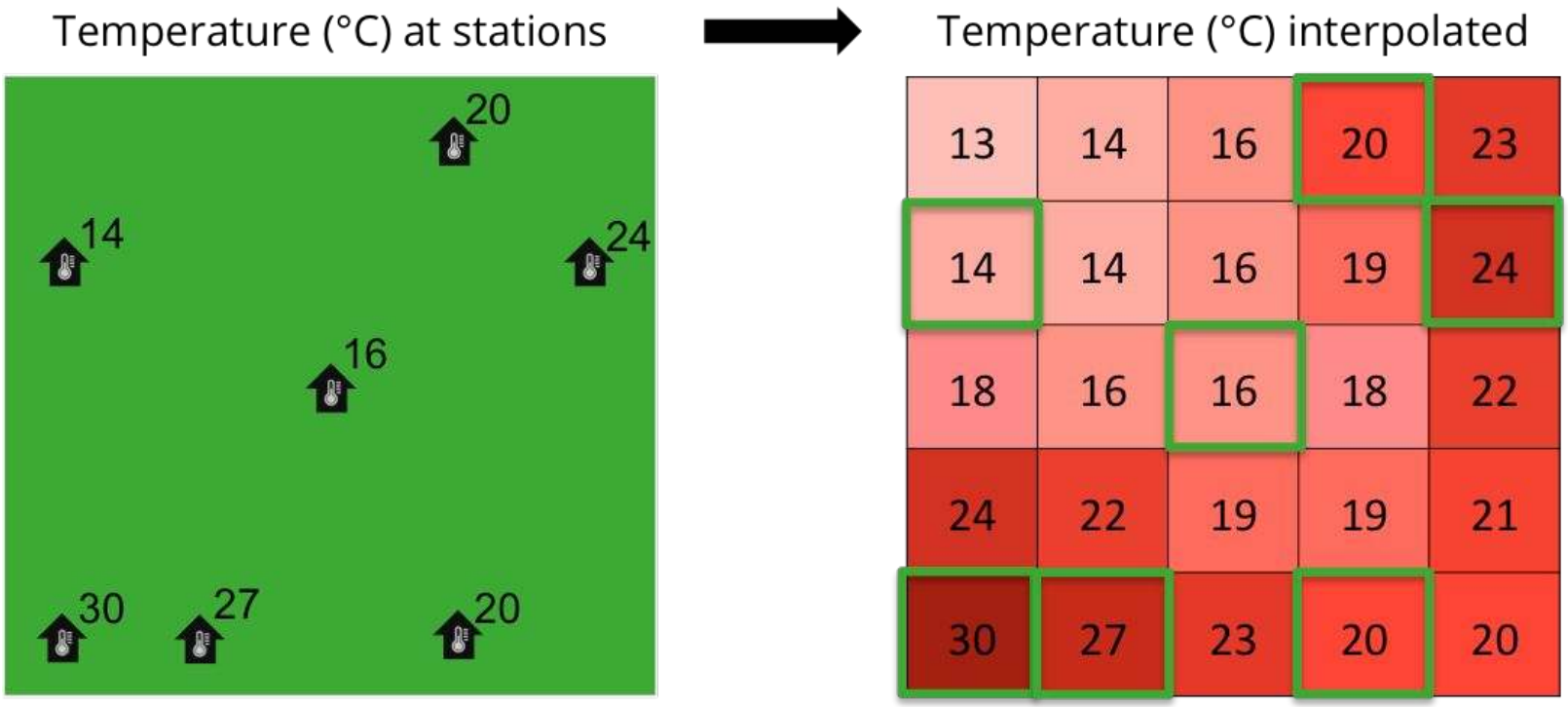



**Valores**
Temperatura
Precipitação
Solo
Porcentagem

# Variáveis ambientais

## Raster - Interpolação

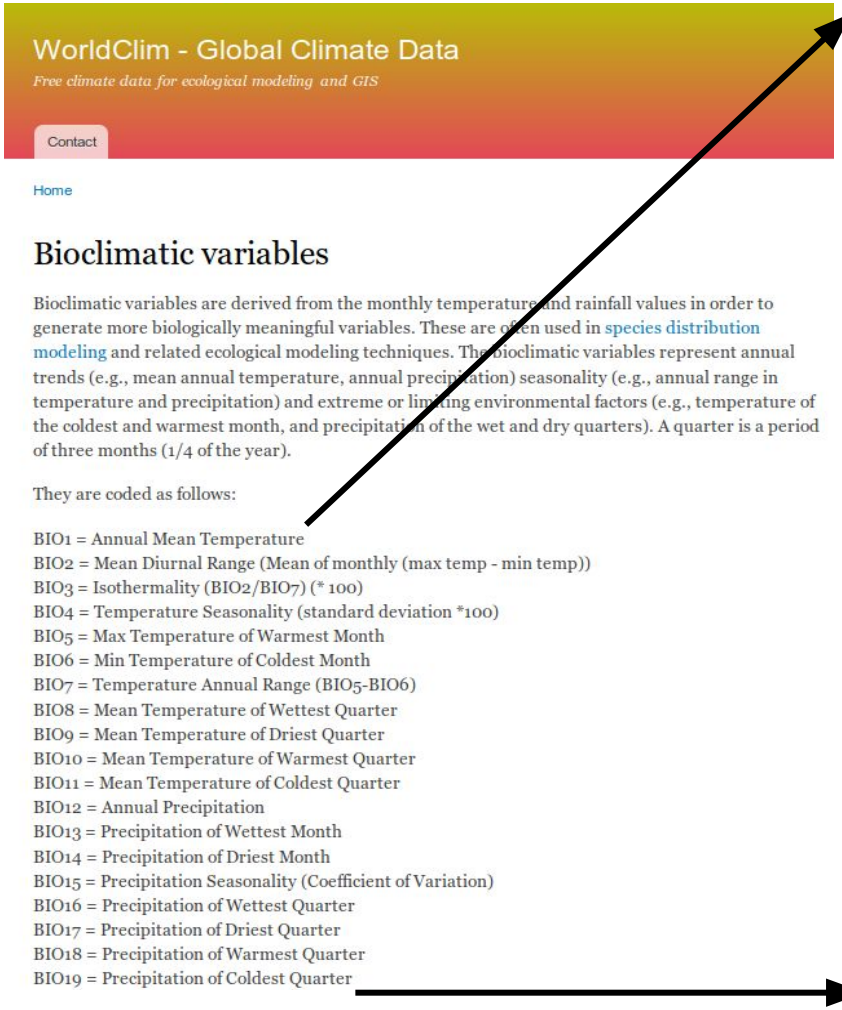
https://support.bccvl.org.au/support/home




Adapted from http://planet.botany.uwc.ac.za/nisl/GIS/spatial/chap_1_11.h

# Variáveis ambientais

## WorldClim - Bioclimáticas




BIO01 = Temperatura média anual
BIO02 = Variação Diurna Média de Temperatura (Média mensal (Tmax-Tmin))
BIO03 = Isotermalidade ((BIO2/BIO7) (* 100))
BIO04 = Sazonalidade da Temperatura (desvio padrão * 100)
BIO05 = Temperatura máxima do mês mais quente
BIO06 = Temperatura mínima do mês mais frio
BIO07 = Amplitude térmica anual (BIO5-BIO6)
BIO08 = Temperatura média do trimestre mais úmido
BIO09 = Temperatura média do trimestre mais seco
BIO10 = Temperatura média do trimestre mais quente
BIO11 = Temperatura média do trimestre mais frio

**Temperatura**

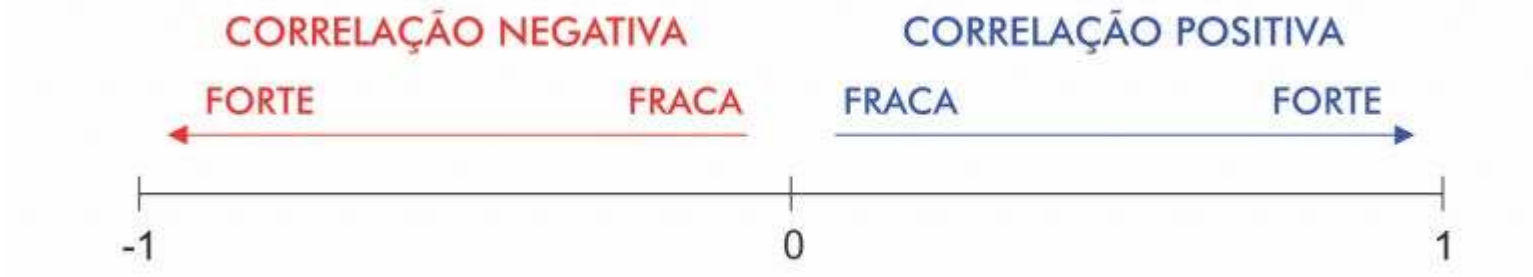
BIO12 = Precipitação Anual
BIO13 = Precipitação do mês mais chuvoso
BIO14 = Precipitação do mês mais seco
BIO15 = Sazonalidade da Precipitação (coeficiente de variação)
BIO16 = Precipitação do trimestre mais chuvoso
BIO17 = Precipitação do trimestre mais seco
BIO18 = Precipitação do trimestre mais quente
BIO19 = Precipitação do trimestre mais frio

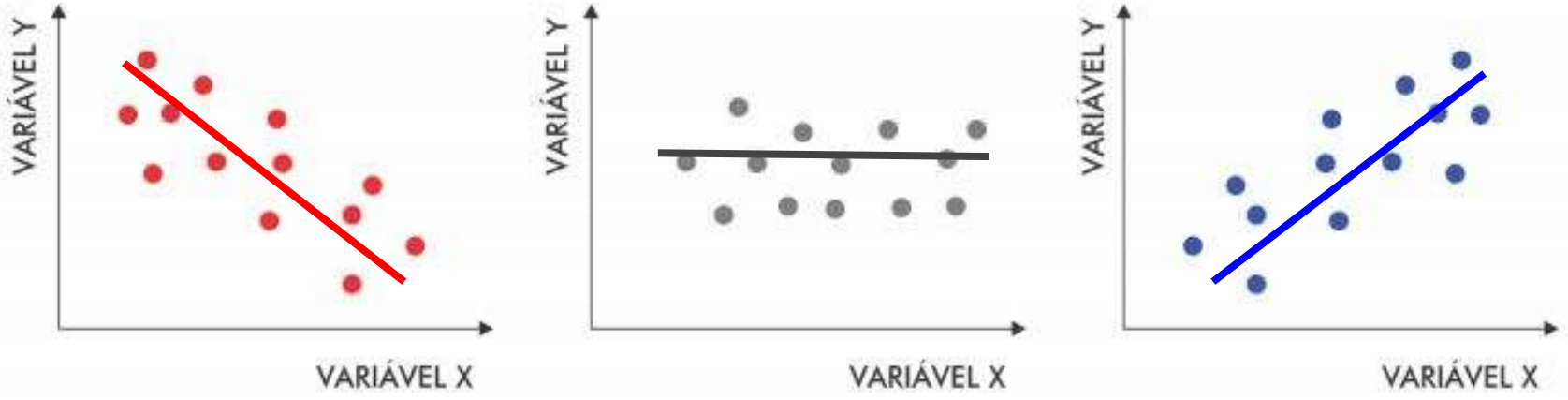
**Precipitação**

# Desafios: Colinearidade

# Variáveis ambientais

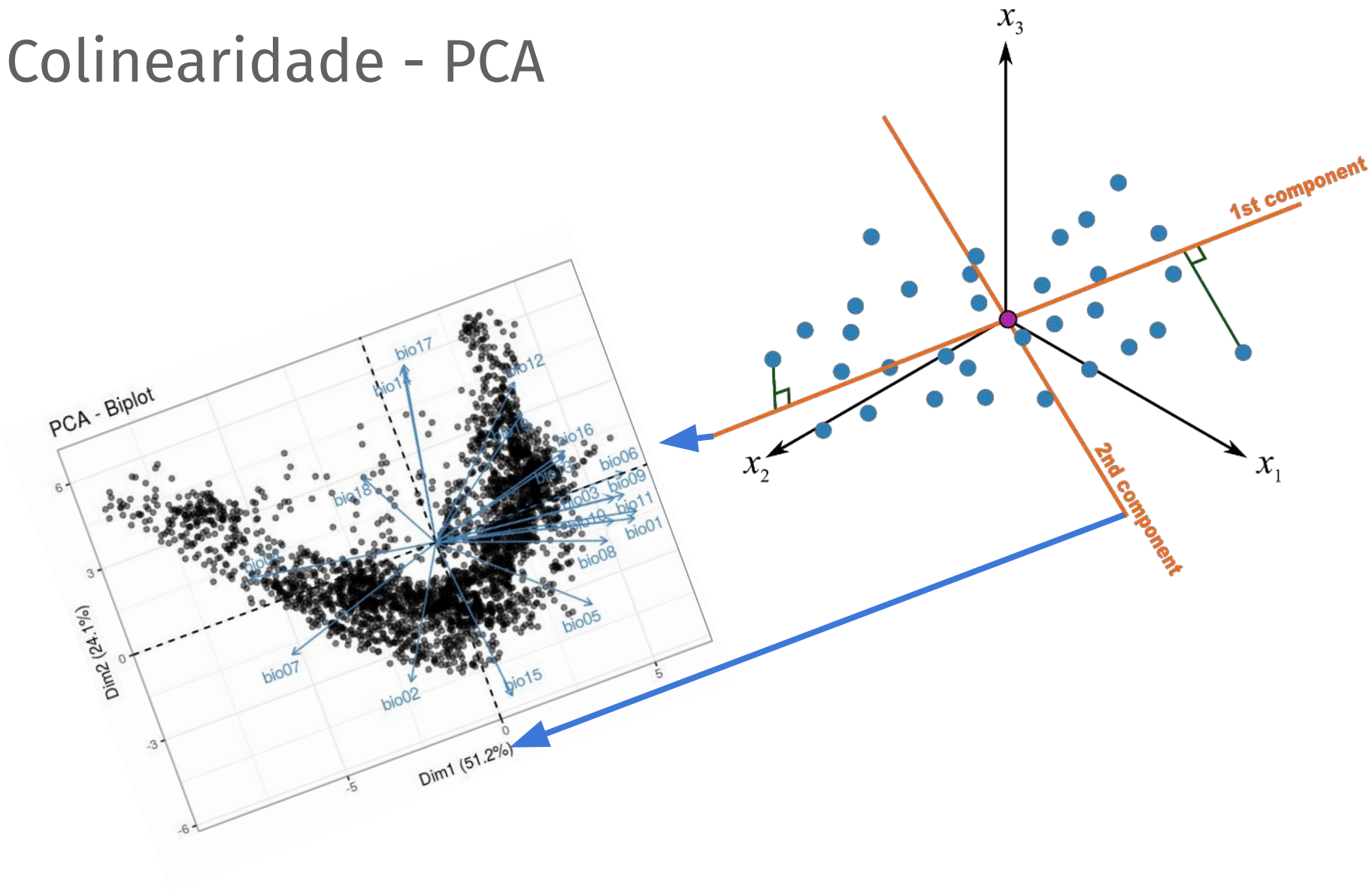
## Colinearidade - Correlação



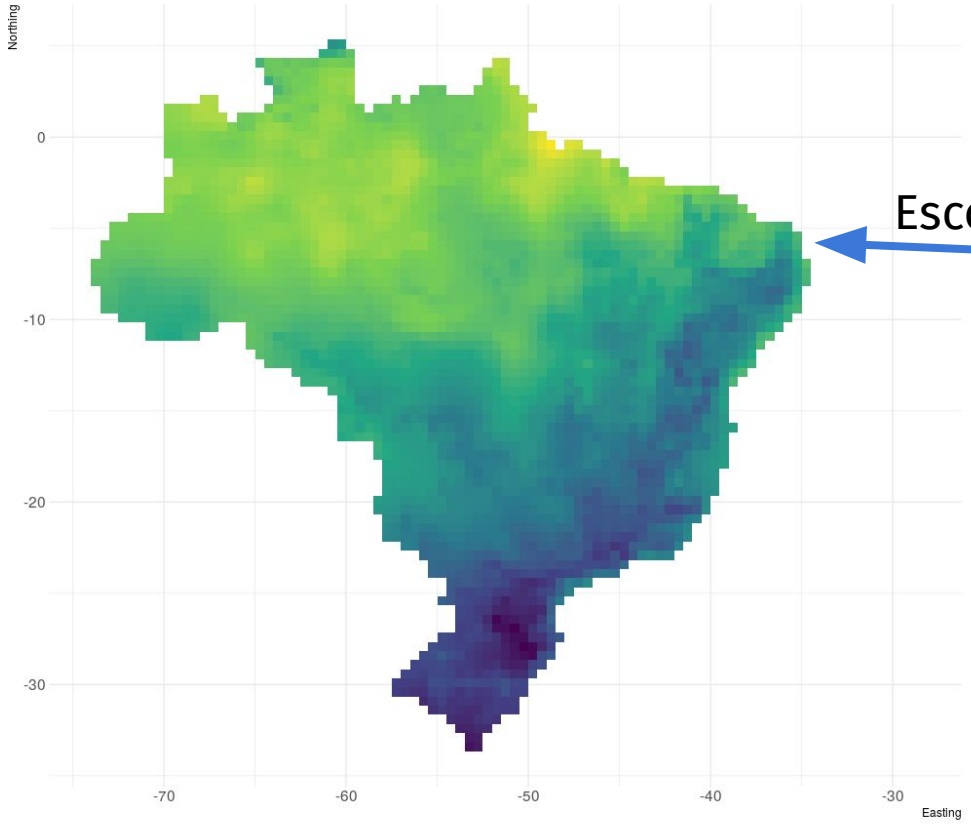
# Variáveis ambientais

## Colinearidade - PCA

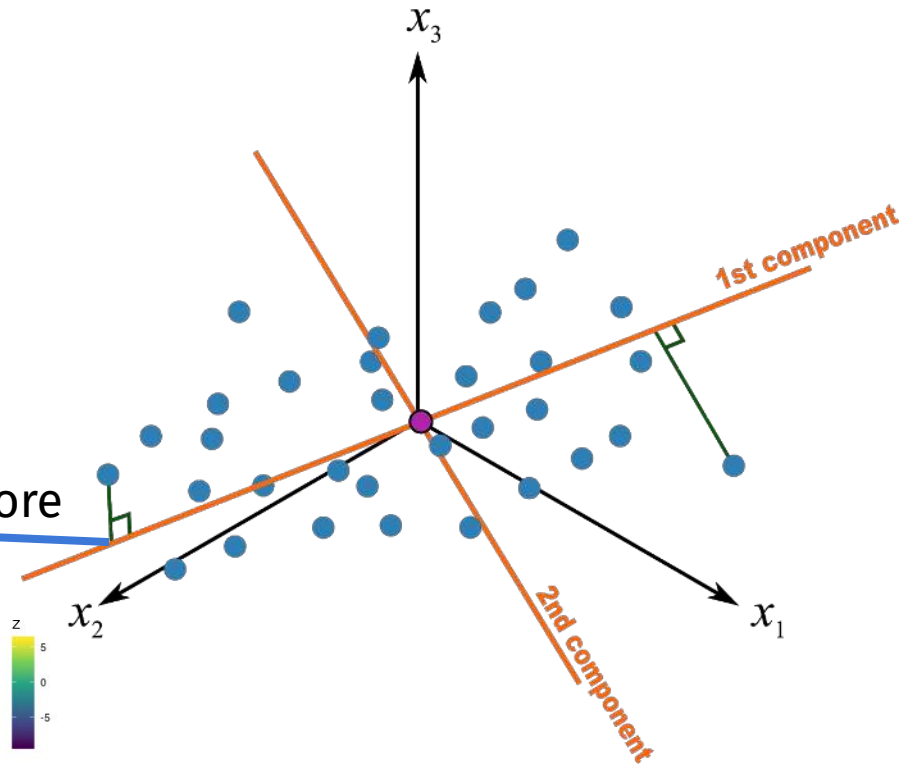


# Variáveis ambientais

## Colinearidade - PCA

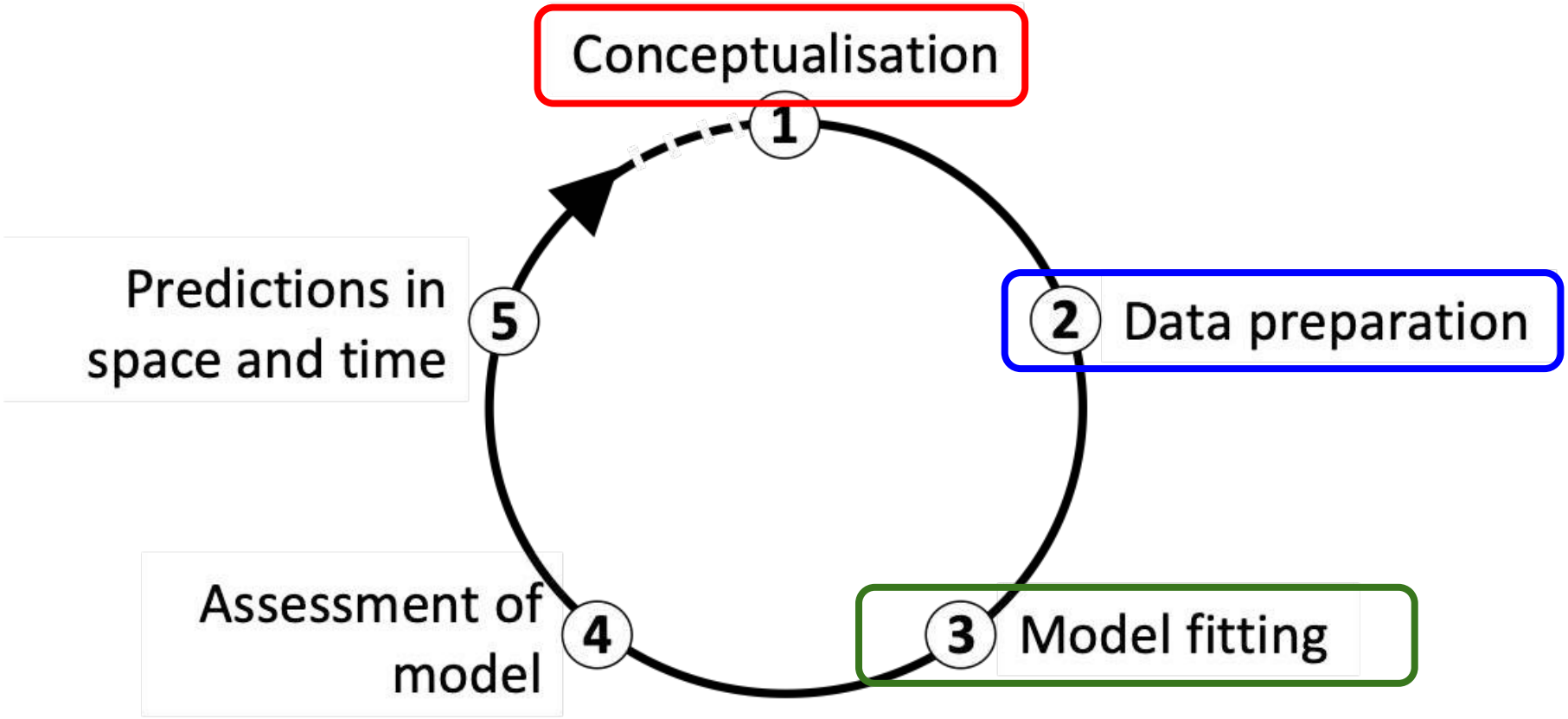



Escore



# SDM passo a passo

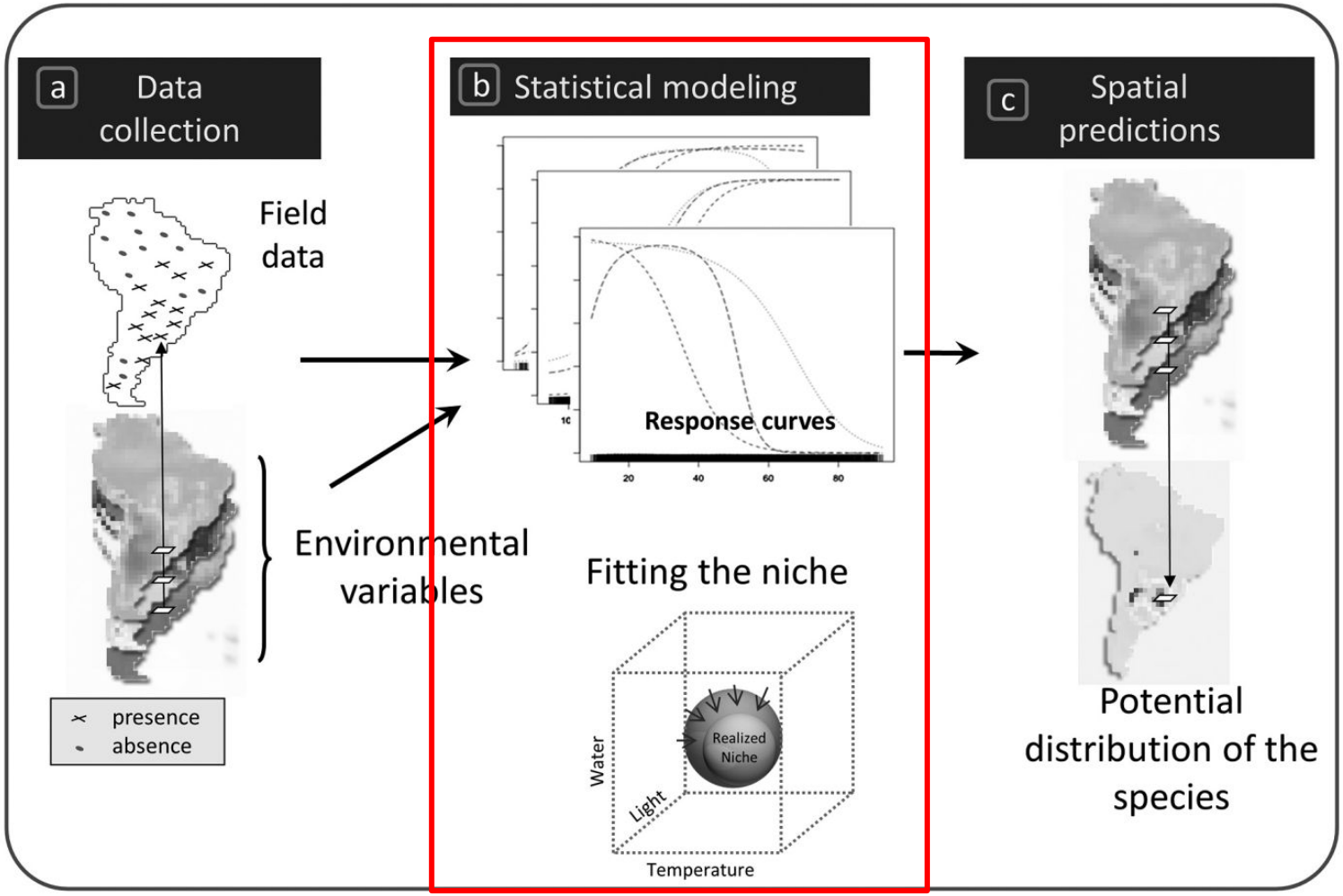
## Estrutura dos SDMs

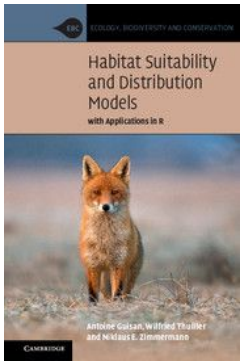


# 6. Ajuste dos modelos

# Ajuste dos SDMs

## Algoritmos estimam o nicho realizado




Guisan et al. (2017)

# Ajuste dos SDMs

## Muitos tipos de algoritmos


Lima-Ribeiro &
Diniz-Filho (2013)

**Apenas presença**

Aquário

- Bioclim
- Dist. Euclidiana
- Dist. Mahalanobis
- Domain (dist. Gower)
- ENFA (ecological niche factor analysis)

**Presença/Background**

- GARP (genetic algoritm for rule-set production)
- Maxent (maximum entropy)
- SVM (support vector machine)

Aprendizado de Máquina
(*machine learning*)
"cofre"

**Presença/Ausência**

Estatístico ("turbina")

- GLMz (generalized linear model)
- GAM (generalized additive model)
- FDA (flexible discriminant analysis)
- MARS (multivariate adaptive reg. splines)
- BRT (boosted regression trees)
  - GBM (gradient boosting machine)
- CART (classification and regression trees)
- RDNFOR (random forest)
- NNET (neural networks)
  - ANN (artificial neural networks)

# Ajuste dos SDMs

## Mais utilizado - MaxEnt


Lima-Ribeiro &
Diniz-Filho (2013)

**Apenas presença**

Aquário

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- Dist. Mahalanobis
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**Presença/Ausência**

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# Ajuste dos SDMs

## Apenas Presença


Lima-Ribeiro &
Diniz-Filho (2013)

Apenas presença

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Dist. Mahalanobis

Domain (dist. Gower)

ENFA (ecological niche factor analysis)

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Maxent (maximum entropy)

SVM (support vector machine)

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"cofre"

Presença/Ausência

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BRT (boosted regression trees)

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CART (classification and regression trees)

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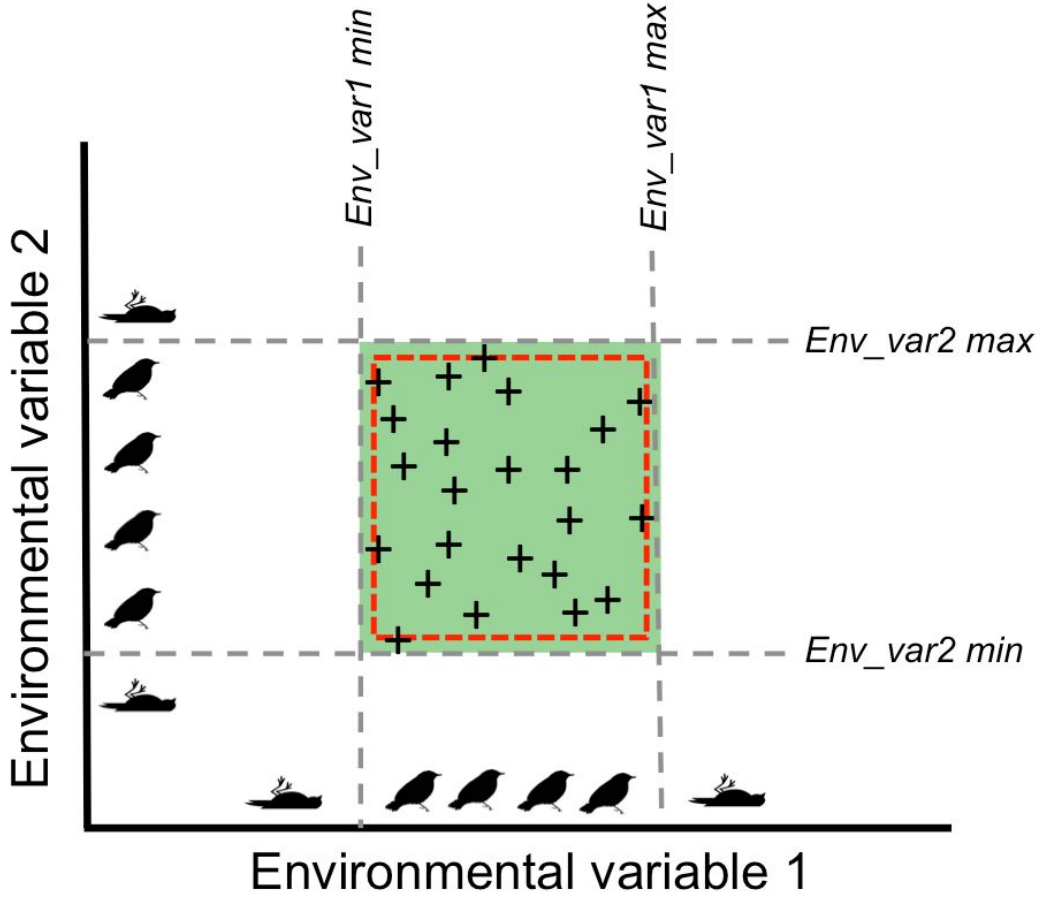
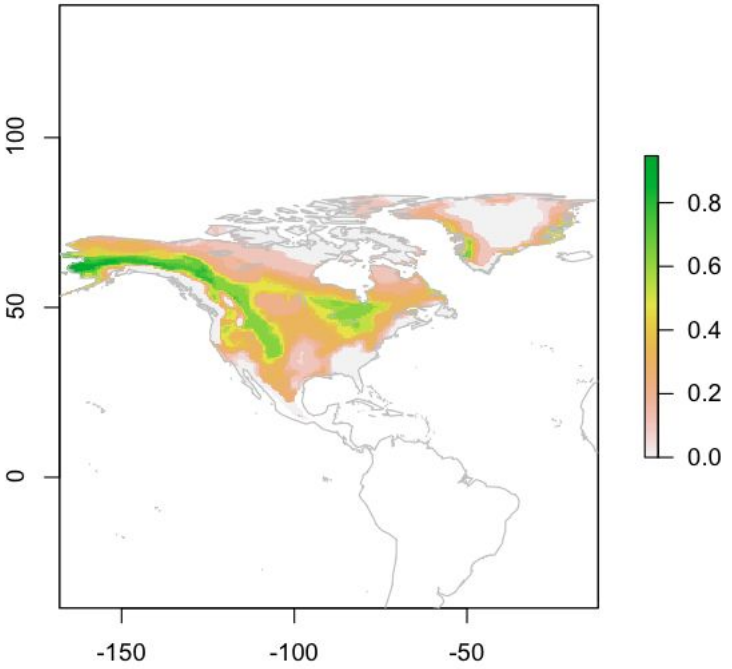
ANN (artificial neural networks)

# Ajuste dos SDMs

## BIOCLIM - Envelope Climático


Lima-Ribeiro &
Diniz-Filho (2013)



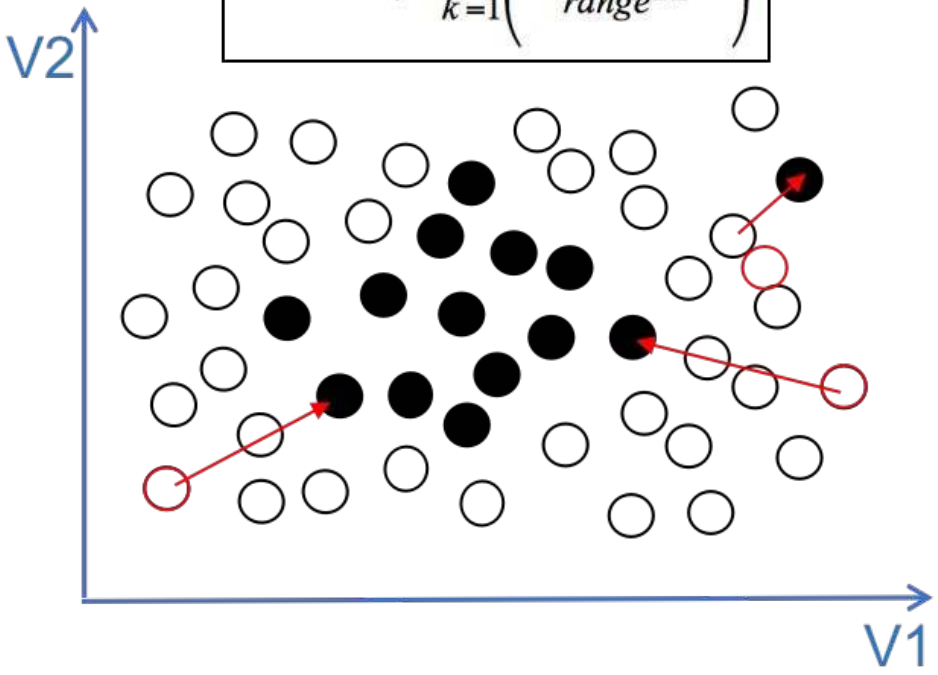



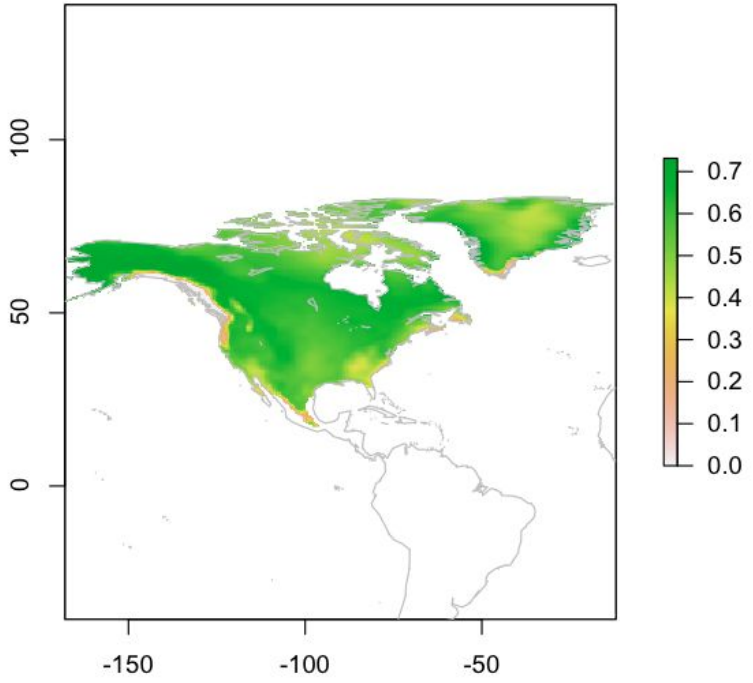
# Ajuste dos SDMs

## DOMAIN - Distância de Gower


Lima-Ribeiro &
Diniz-Filho (2013)

$$d_{AB} = \frac{1}{V}\sum_{k=1}^{V}\left(\frac{|A_K - B_K|}{range K}\right)$$



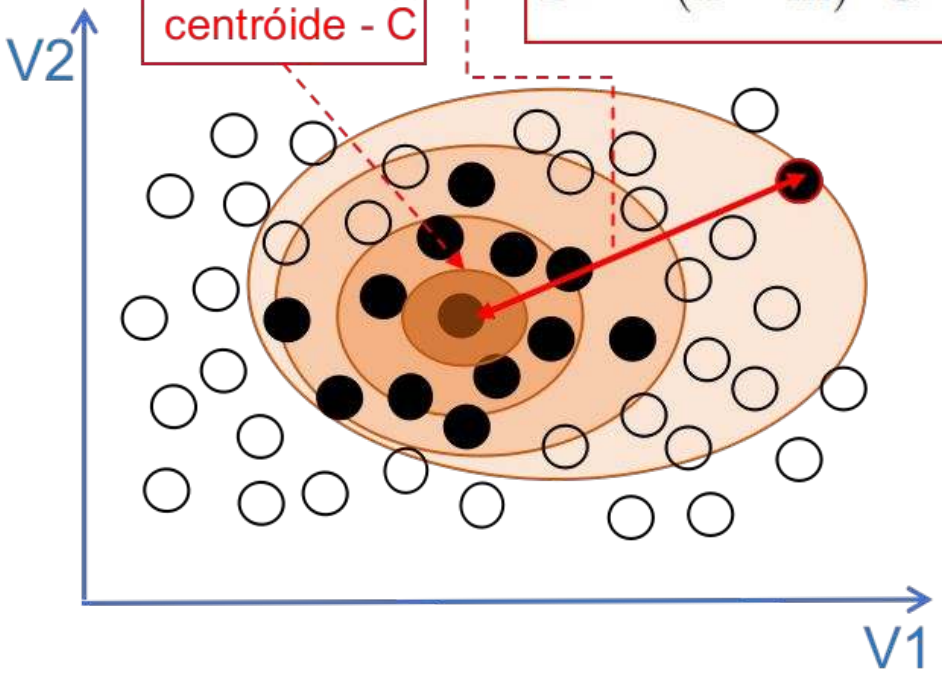



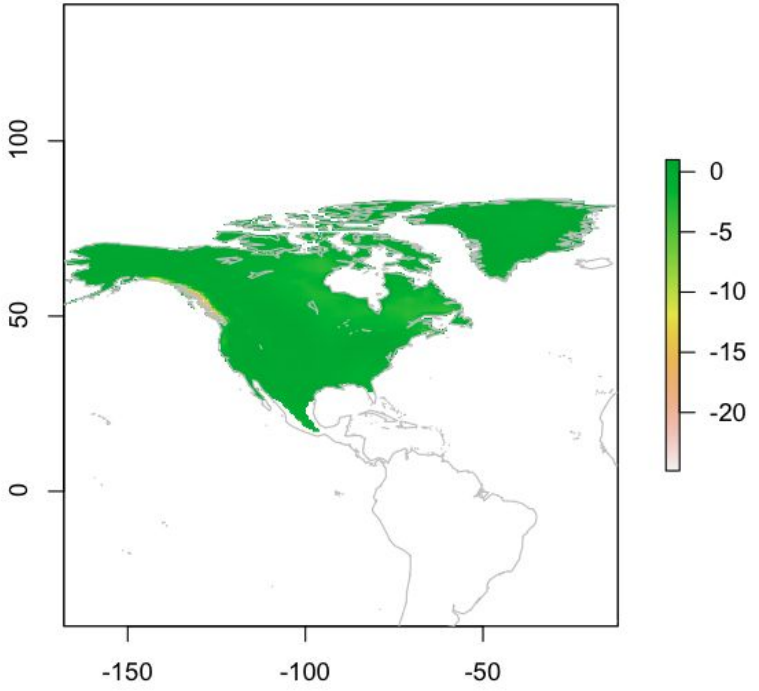
# Ajuste dos SDMs

## Distância de Mahalanobis


Lima-Ribeiro &
Diniz-Filho (2013)

$$D^2 = (\bar{\mathbf{x}} - \bar{\mathbf{m}})^T \mathbf{C}^{-1} (\bar{\mathbf{x}} - \bar{\mathbf{m}})$$



# Ajuste dos SDMs

## Presença/Background (plano de fundo)


Lima-Ribeiro &
Diniz-Filho (2013)

**Apenas presença**

Aquário

- Bioclim
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- Dist. Mahalanobis
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**Presença/Background**

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Aprendizado de Máquina
(*machine learning*)
"cofre"

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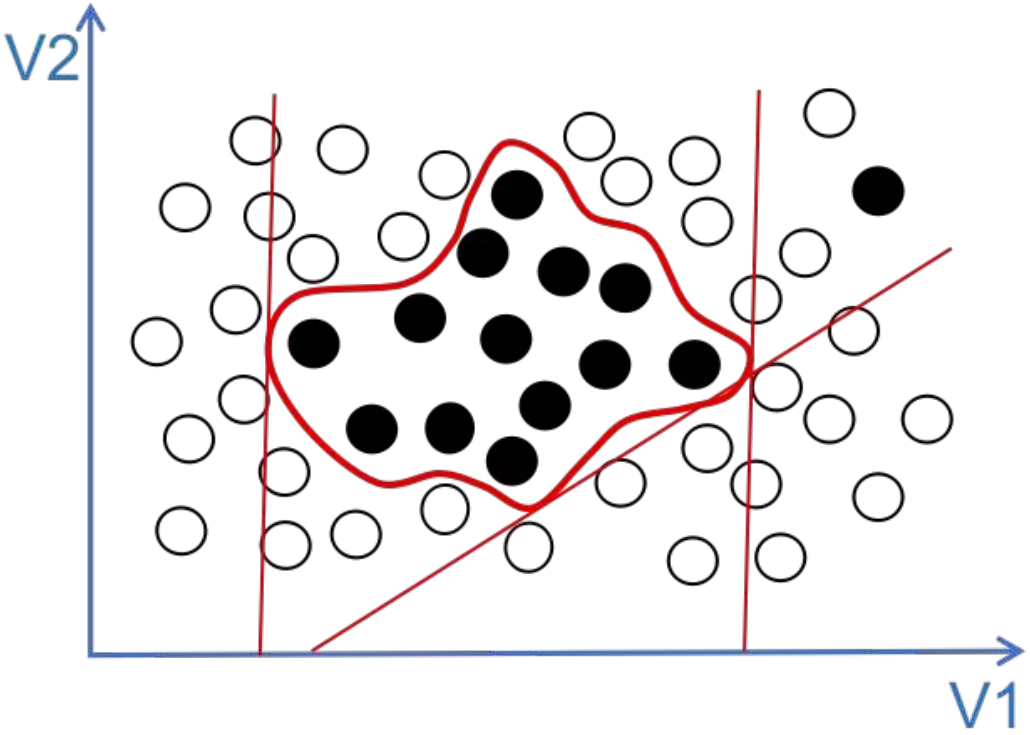
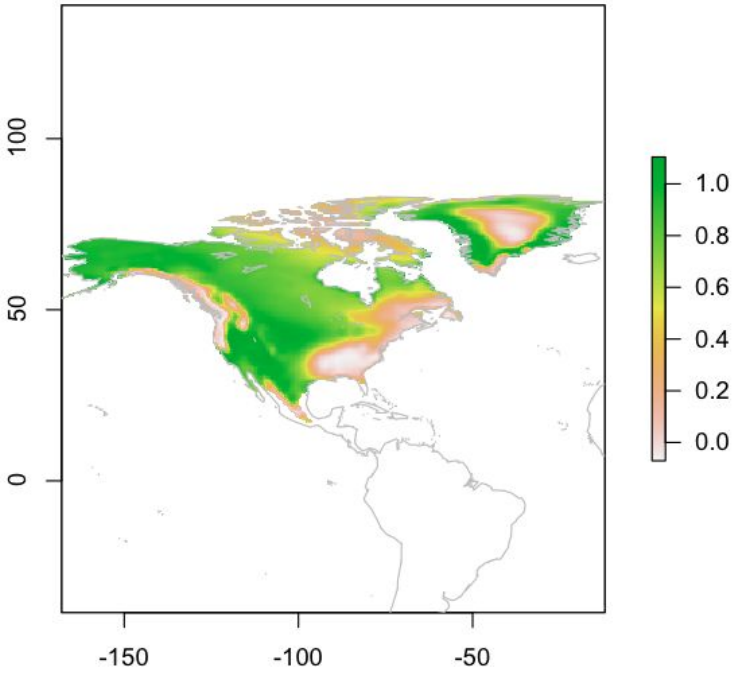
  - ANN (artificial neural networks)

# Ajuste dos SDMs

## Support Vector Machine (SVM)

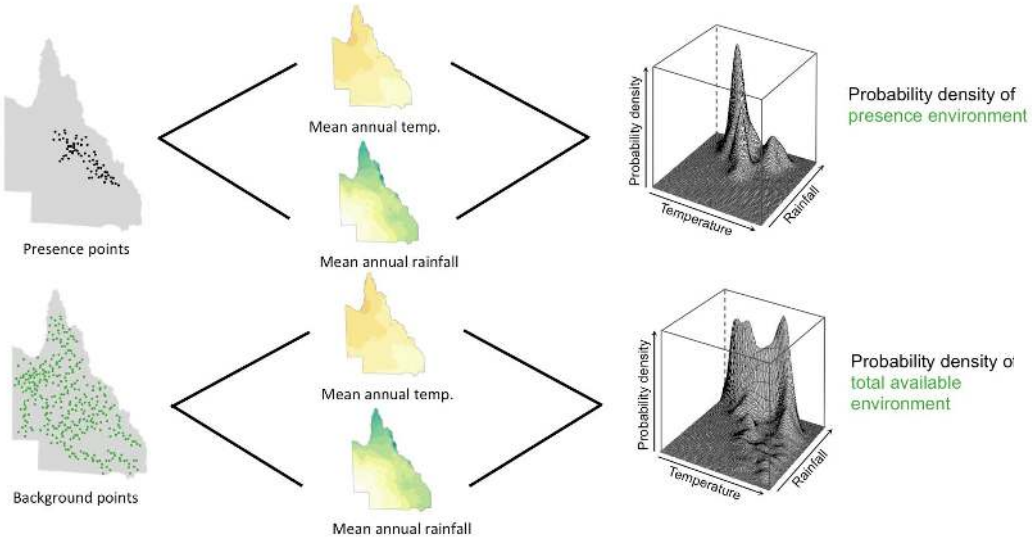

Lima-Ribeiro &
Diniz-Filho (2013)



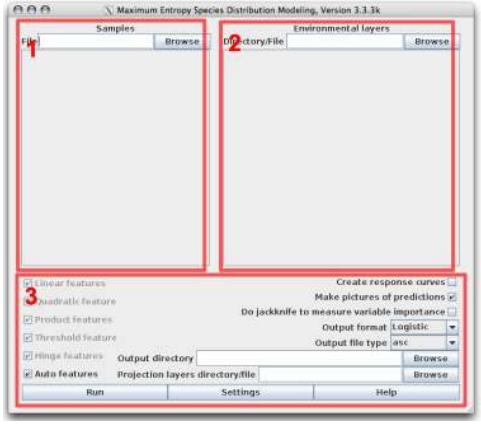



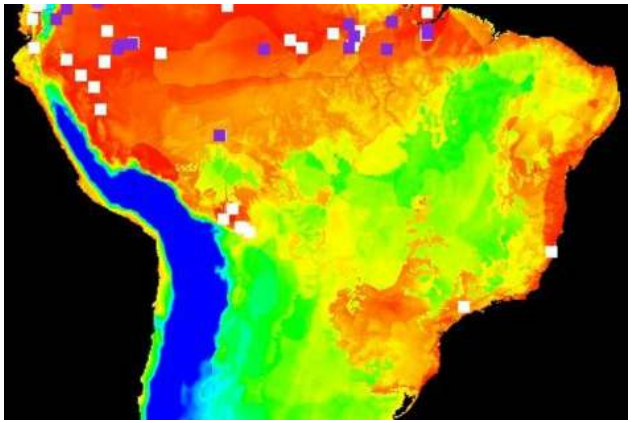
# Ajuste dos SDMs

## Maximum Entropy (MaxEnt)

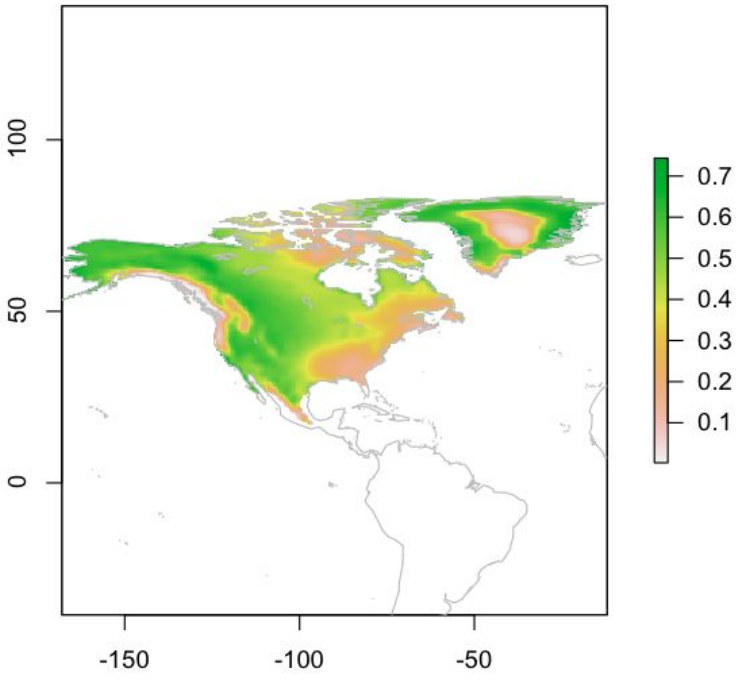



Adapted from Elith et al. (2011) *A statistical explanation of MaxEnt for ecologists*. Diversity and Distributions, 17, 43-57.



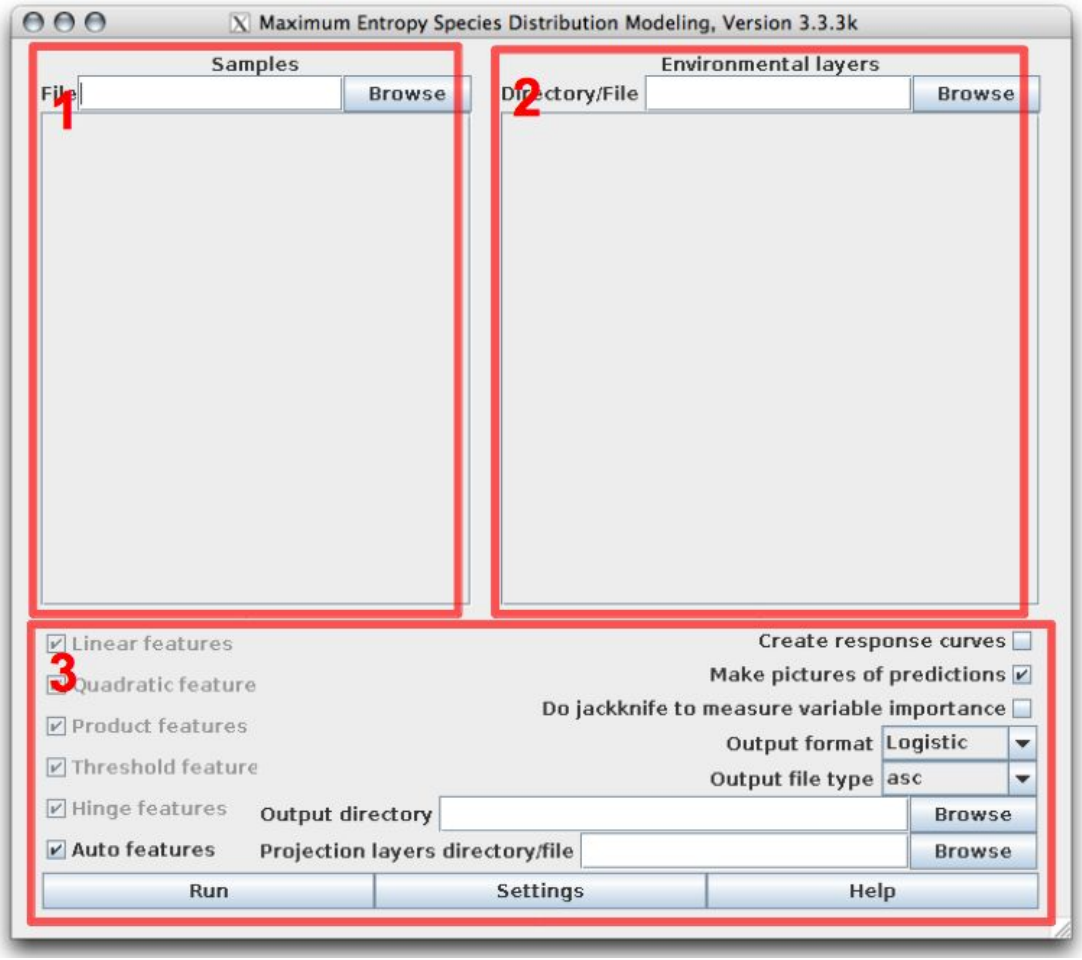



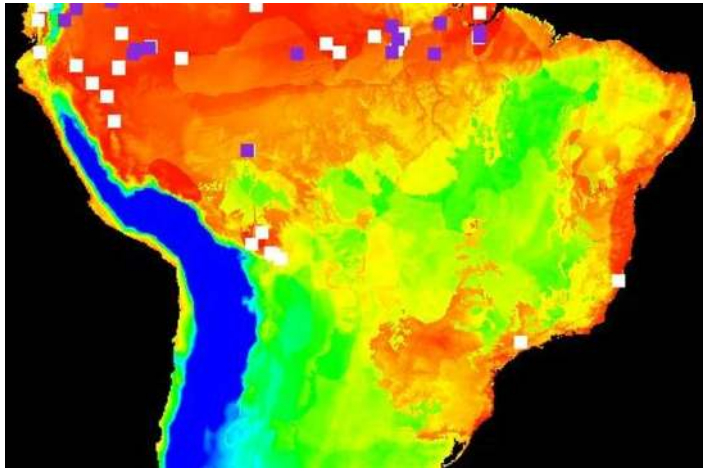

Lima-Ribeiro &
Diniz-Filho (2013)

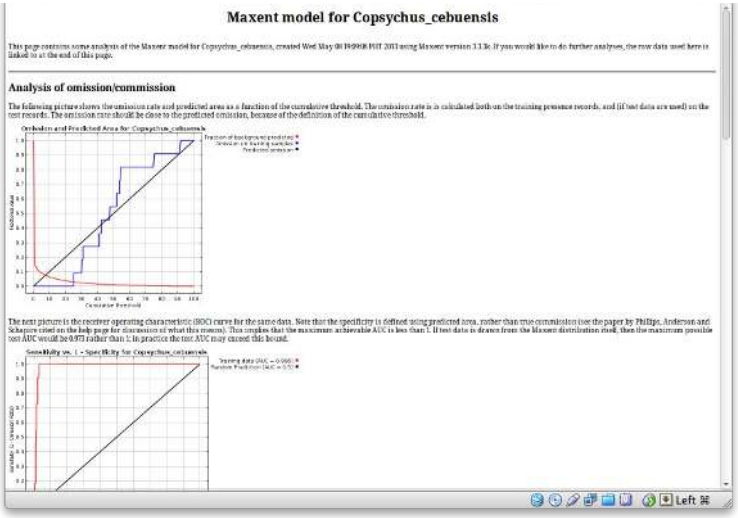


# Ajuste dos SDMs

## Maximum Entropy (MaxEnt)





# Ajuste dos SDMs

## Presença e ausência


Lima-Ribeiro &
Diniz-Filho (2013)

**Apenas presença**

Aquário

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Aprendizado de Máquina
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  - ANN (artificial neural networks)

# Onde encontrar dados de ausência?

# Ajuste dos SDMs

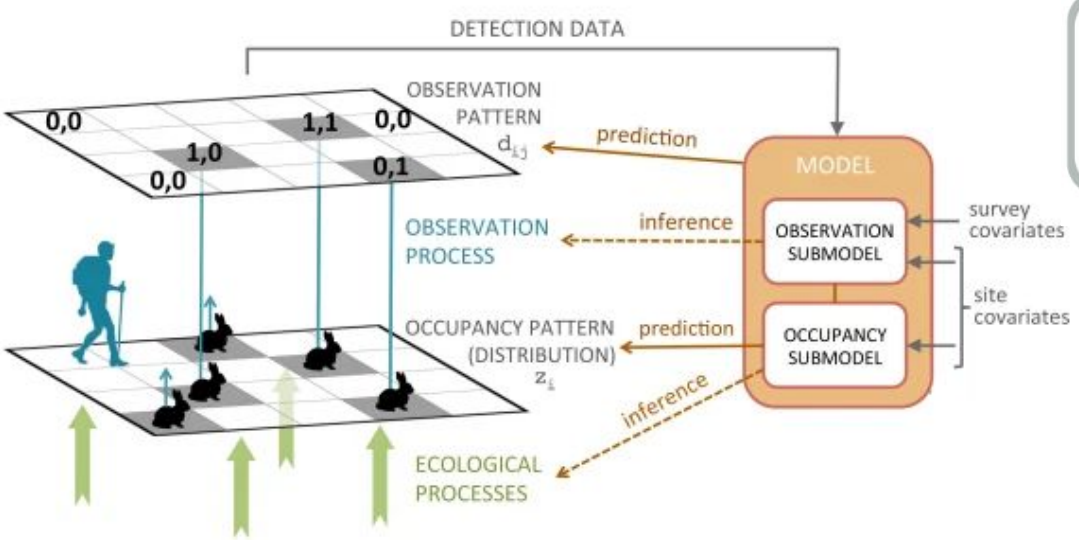
## Ausência “real” (modelos de ocupação)

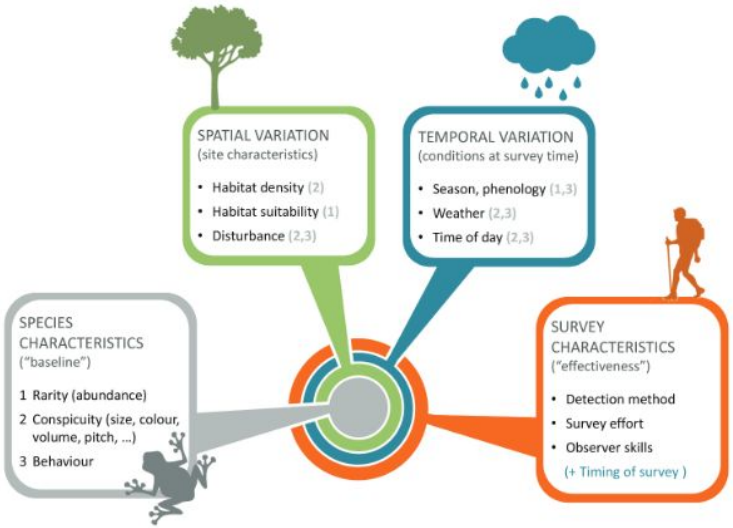
**Modelling of species distributions, range dynamics and communities under imperfect detection: advances, challenges and opportunities**

**Gurutzeta Guillera-Arroita**

**Ecography 40: 281–295, 2017**
doi: 10.1111/ecog.02445

Subject Editor: Miguel Araújo. Editor-in-Chief: Miguel Araújo. Accepted 15 June 2016

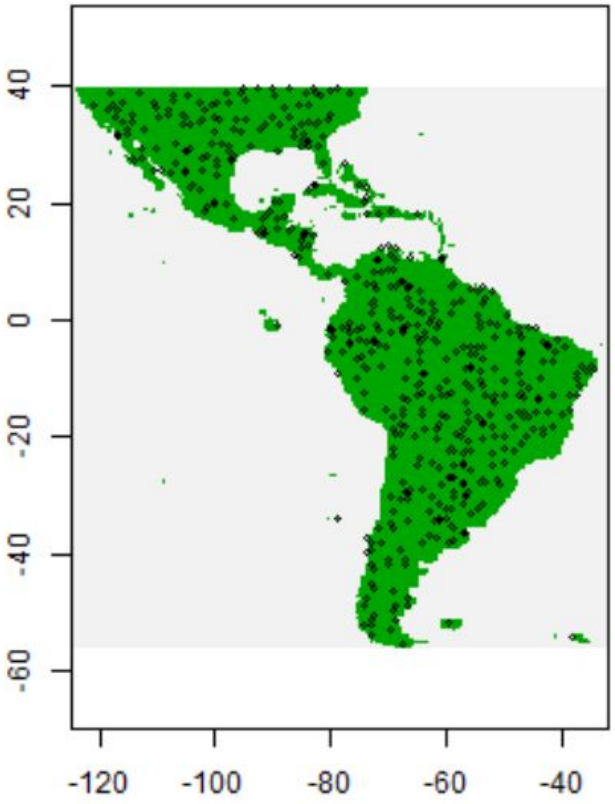


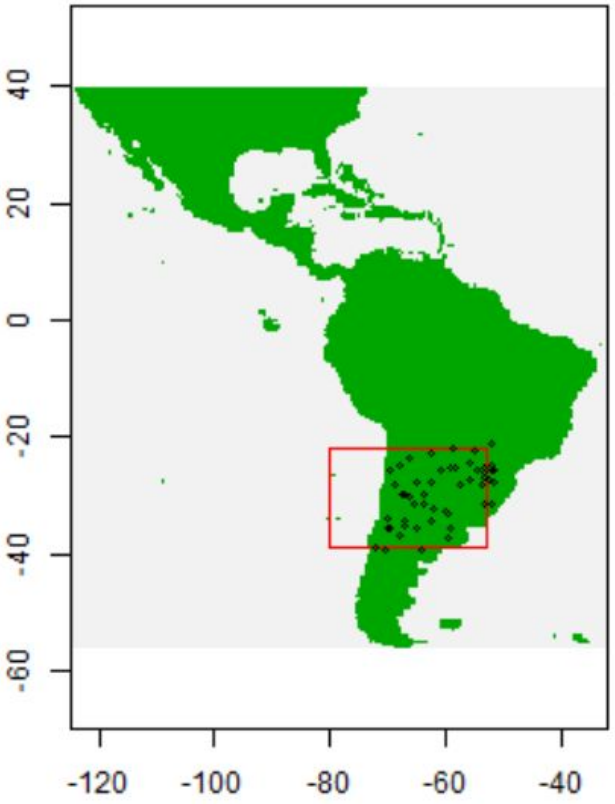



# Ajuste dos SDMs

## Pseudo-ausência

Sorteio de **pontos aleatórios** (sem **padrão espacial**) para serem considerados como **ausência verdadeira**

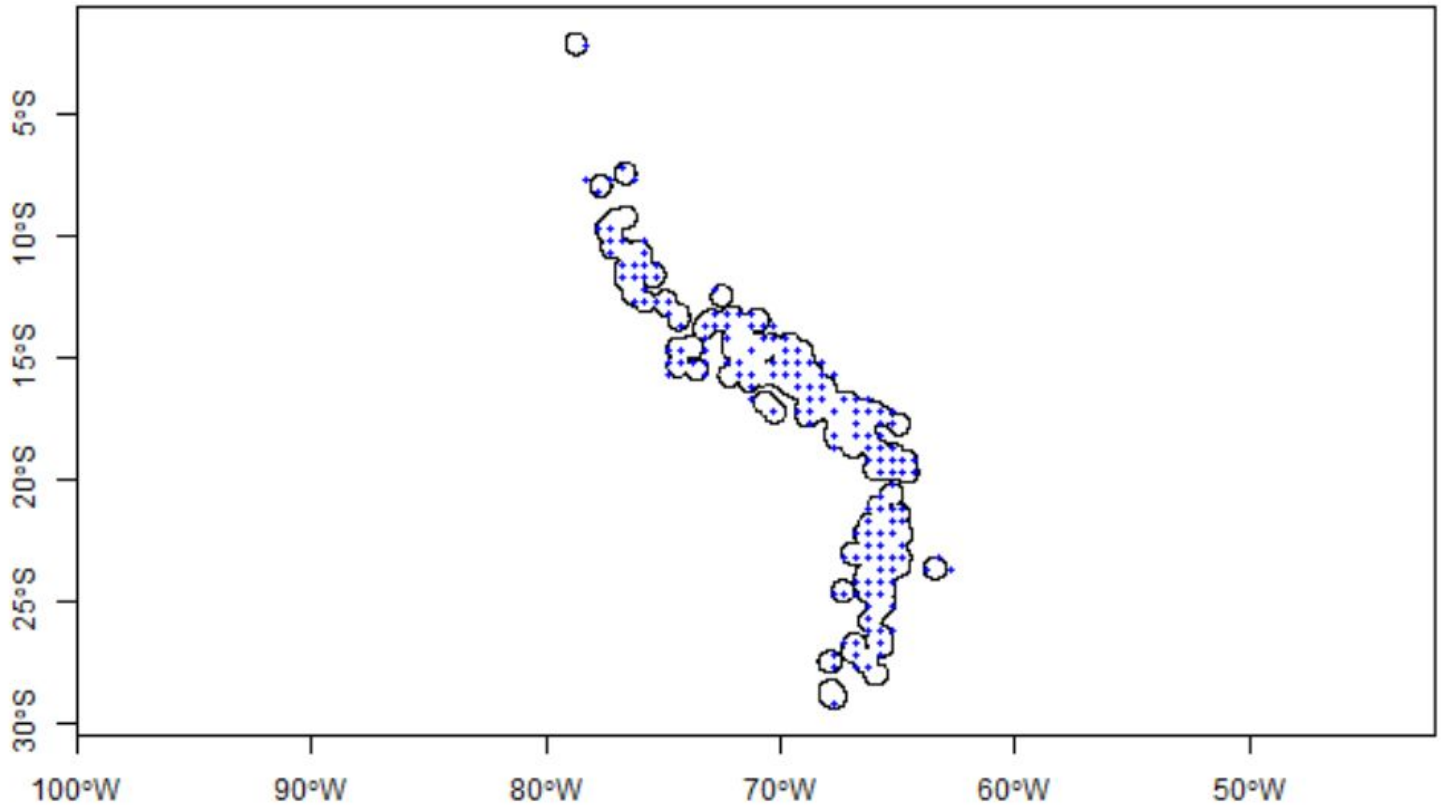


# Ajuste dos SDMs

## Pseudo-ausência

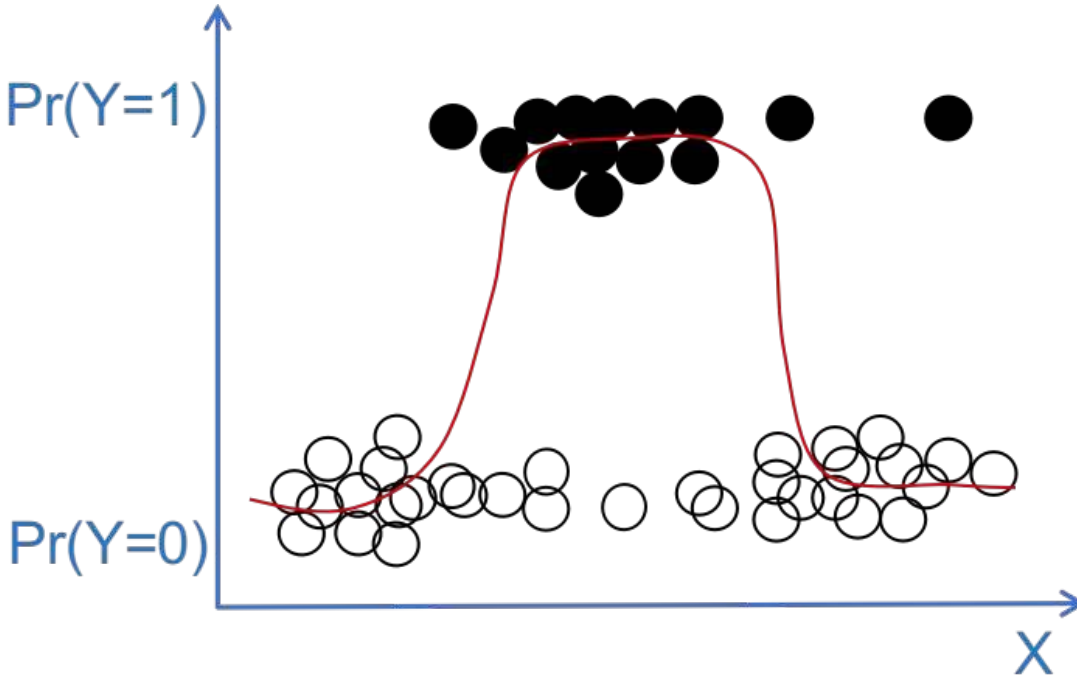
Sorteio de **pontos aleatórios** (com **padrão espacial**) para serem considerados como **ausência verdadeira**

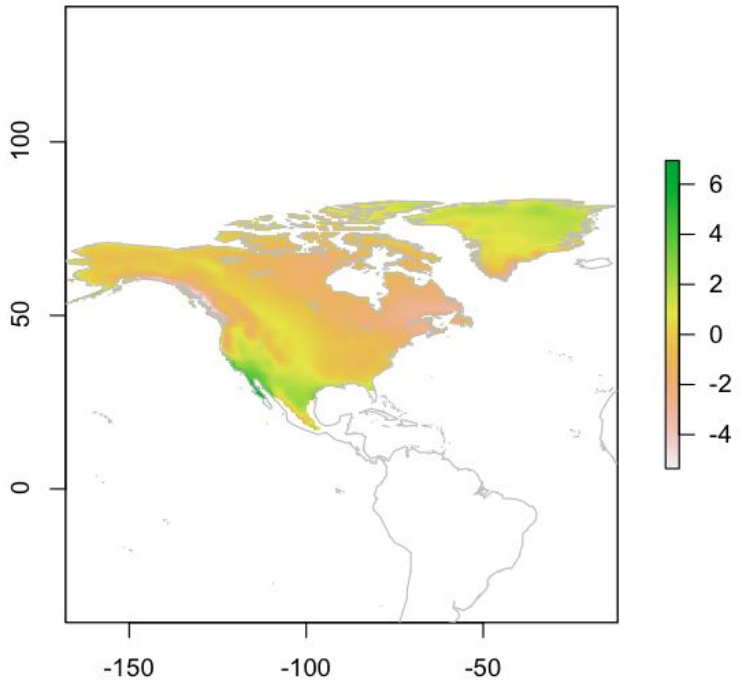


# Ajuste dos SDMs

## Generalized Linear Models (GLM)

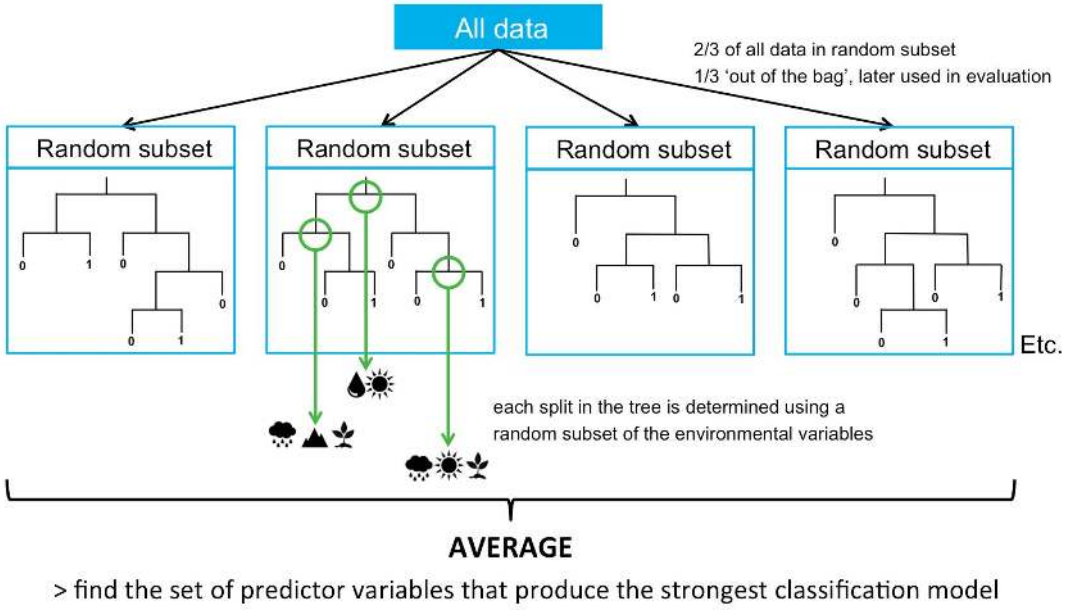

Lima-Ribeiro &
Diniz-Filho (2013)



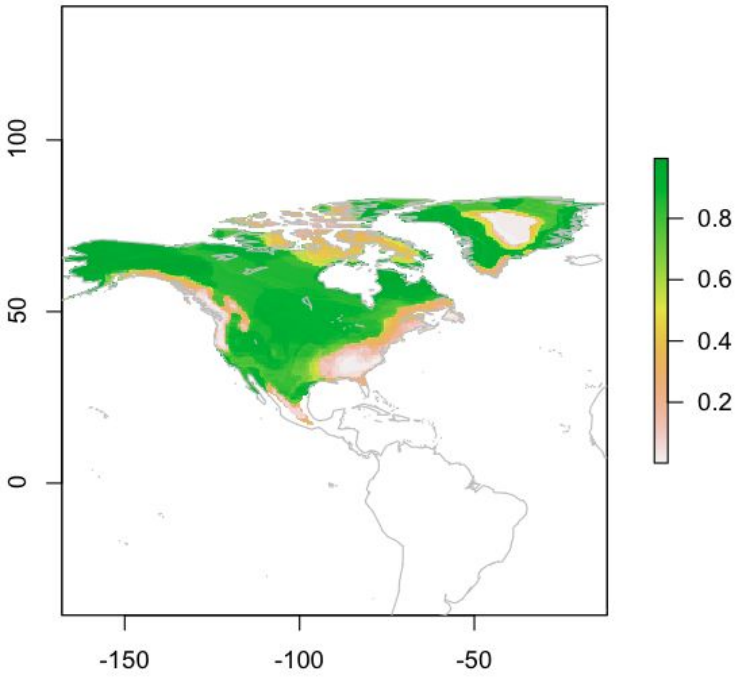
# Ajuste dos SDMs

## Random Forest



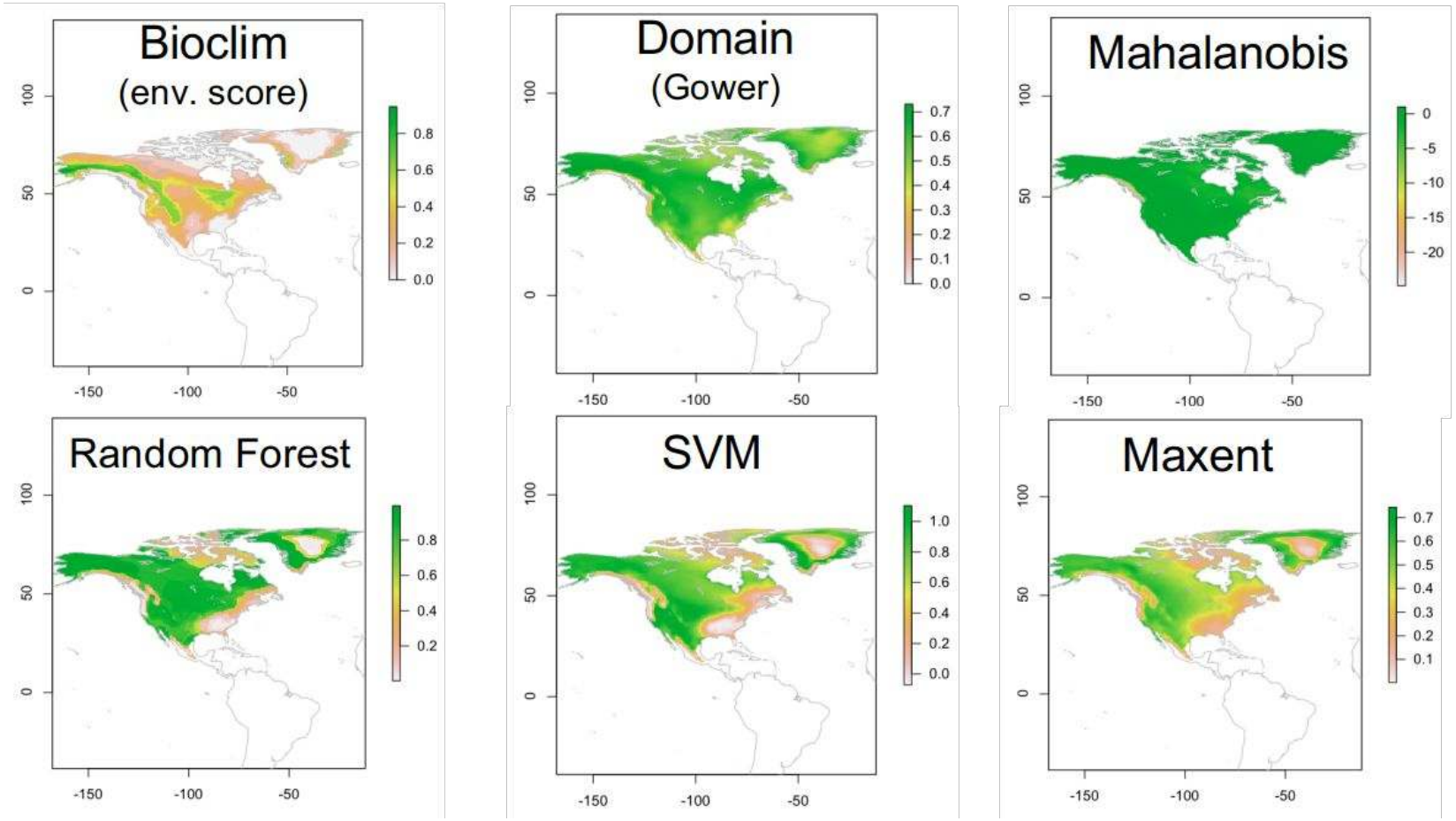

> find the set of predictor variables that produce the strongest classification model


Lima-Ribeiro &
Diniz-Filho (2013)



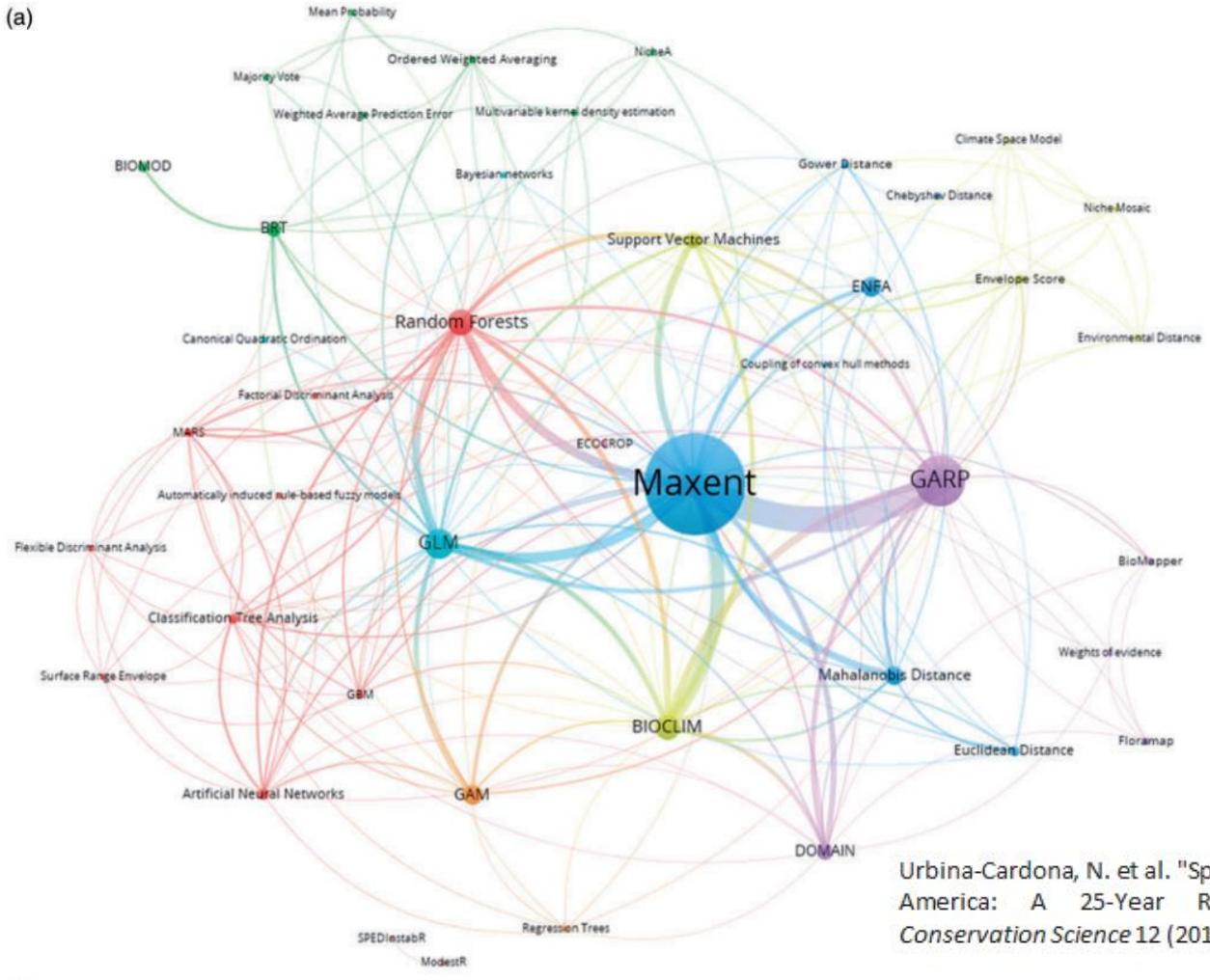
# Ajuste dos SDMs

## Qual algoritmo usar?



# Ajuste dos SDMs

## Uso dos algoritmos (Am. Latina - últimos 25 anos)




Urbina-Cardona, N. et al. "Species Distribution Modeling in Latin America: A 25-Year Retrospective Review." *Tropical Conservation Science* 12 (2019).

# Ajuste dos SDMs

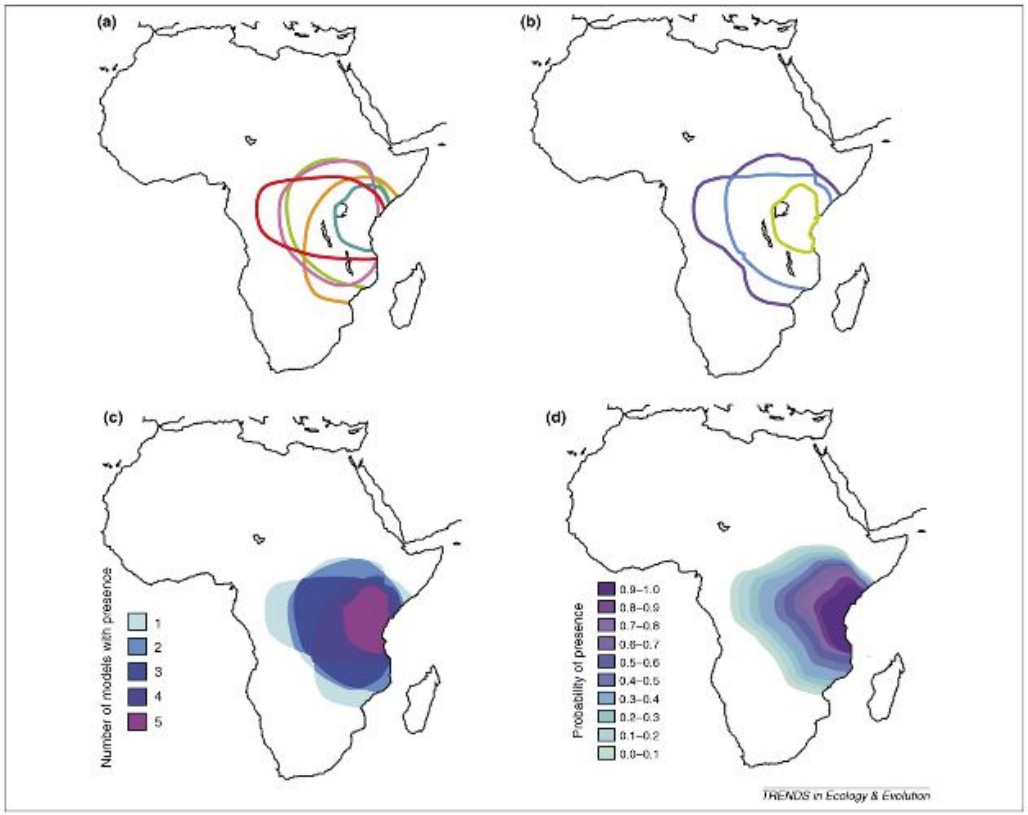
## Consenso *(Ensemble)*

Review TRENDS in Ecology and Evolution Vol.22 No.1



### Ensemble forecasting of species distributions

Miguel B. Araújo[1] and Mark New[2]



# Ajuste dos SDMs

## Consenso *(Ensemble)*

**Novel methods improve prediction of species' distributions from occurrence data**

Jane Elith*, Catherine H. Graham*, Robert P. Anderson, Miroslav Dudík, Simon Ferrier, Antoine Guisan, Robert J. Hijmans, Falk Huettmann, John R. Leathwick, Anthony Lehmann, Jin Li, Lucia G. Lohmann, Bette A. Loiselle, Glenn Manion, Craig Moritz, Miguel Nakamura, Yoshinori Nakazawa, Jacob McC. Overton, A. Townsend Peterson, Steven J. Phillips, Karen Richardson, Ricardo Scachetti-Pereira, Robert E. Schapire, Jorge Soberón, Stephen Williams, Mary S. Wisz and Niklaus E. Zimmermann

ECOGRAPHY 29: 129–151, 2006

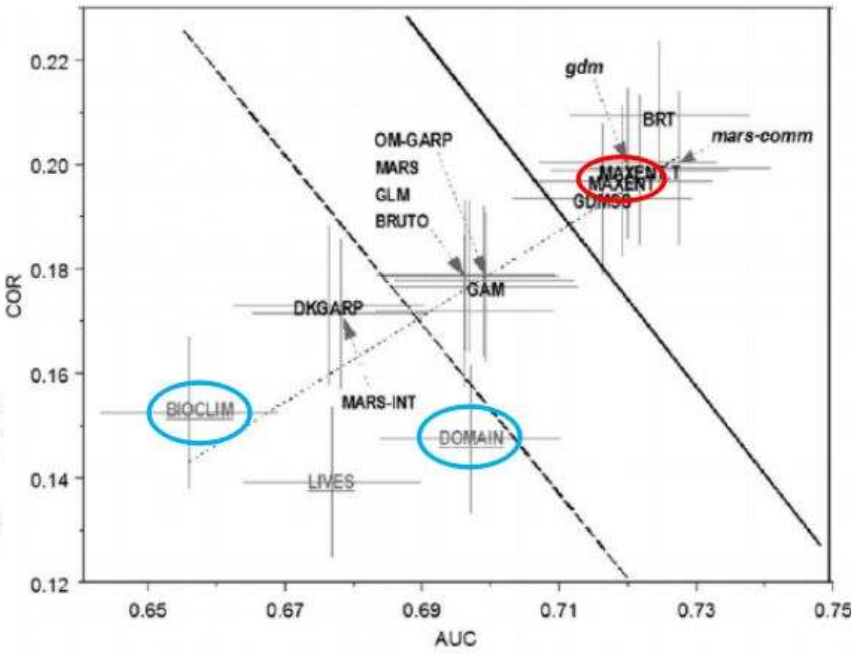



Fig. 3. Mean AUC vs mean correlation (COR) for modelling methods, summarised across all species. The grey bars are standard errors estimated in the GLMM (see Appendix), reflecting variation for an average species in an average region. The labels are broad classifications of the methods: grey underlined = only use presence data, black capitals = use presence and background samples, black lower case italics = community methods.

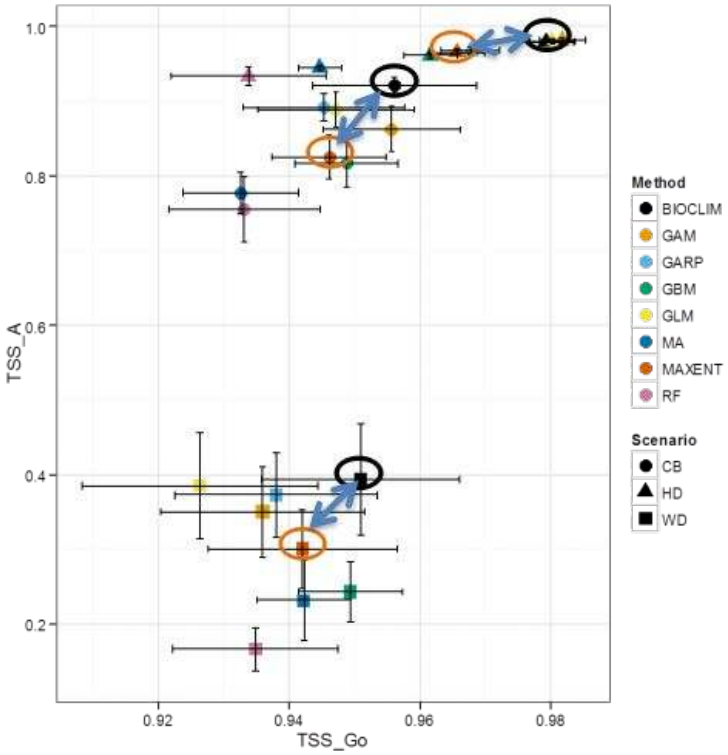
# Ajuste dos SDMs

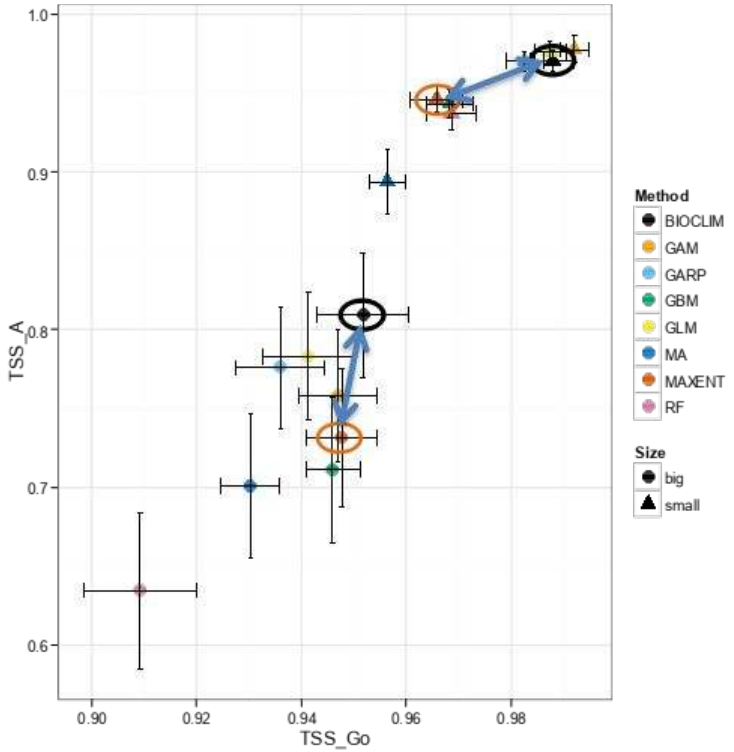
## Consenso *(Ensemble)*

Methods in Ecology and Evolution
BRITISH ECOLOGICAL SOCIETY
Research Article Free Access

**No silver bullets in correlative ecological niche modelling: insights from testing among many potential algorithms for niche estimation**

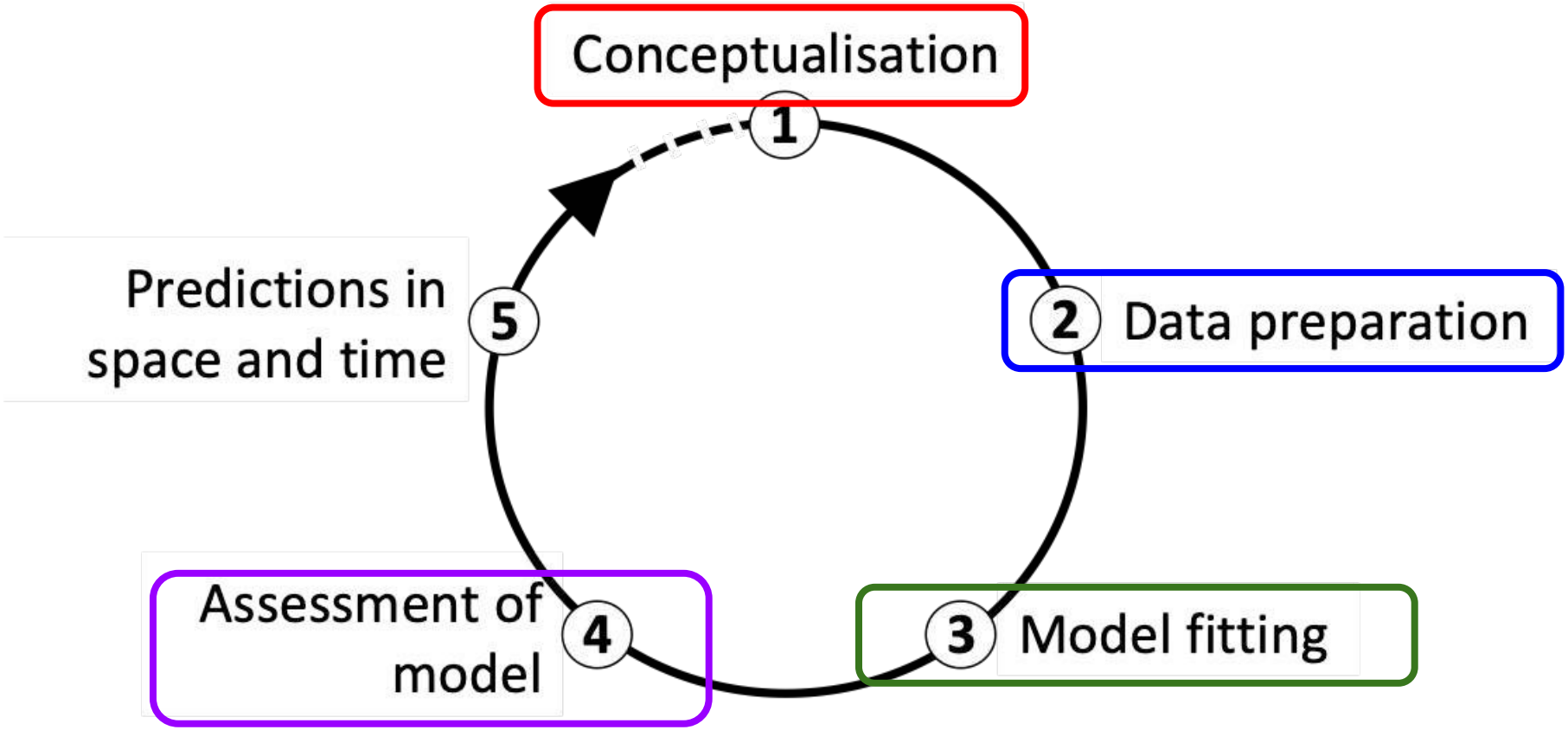
Huijie Qiao, Jorge Soberón, Andrew Townsend Peterson



# SDM passo a passo

## Estrutura dos SDMs

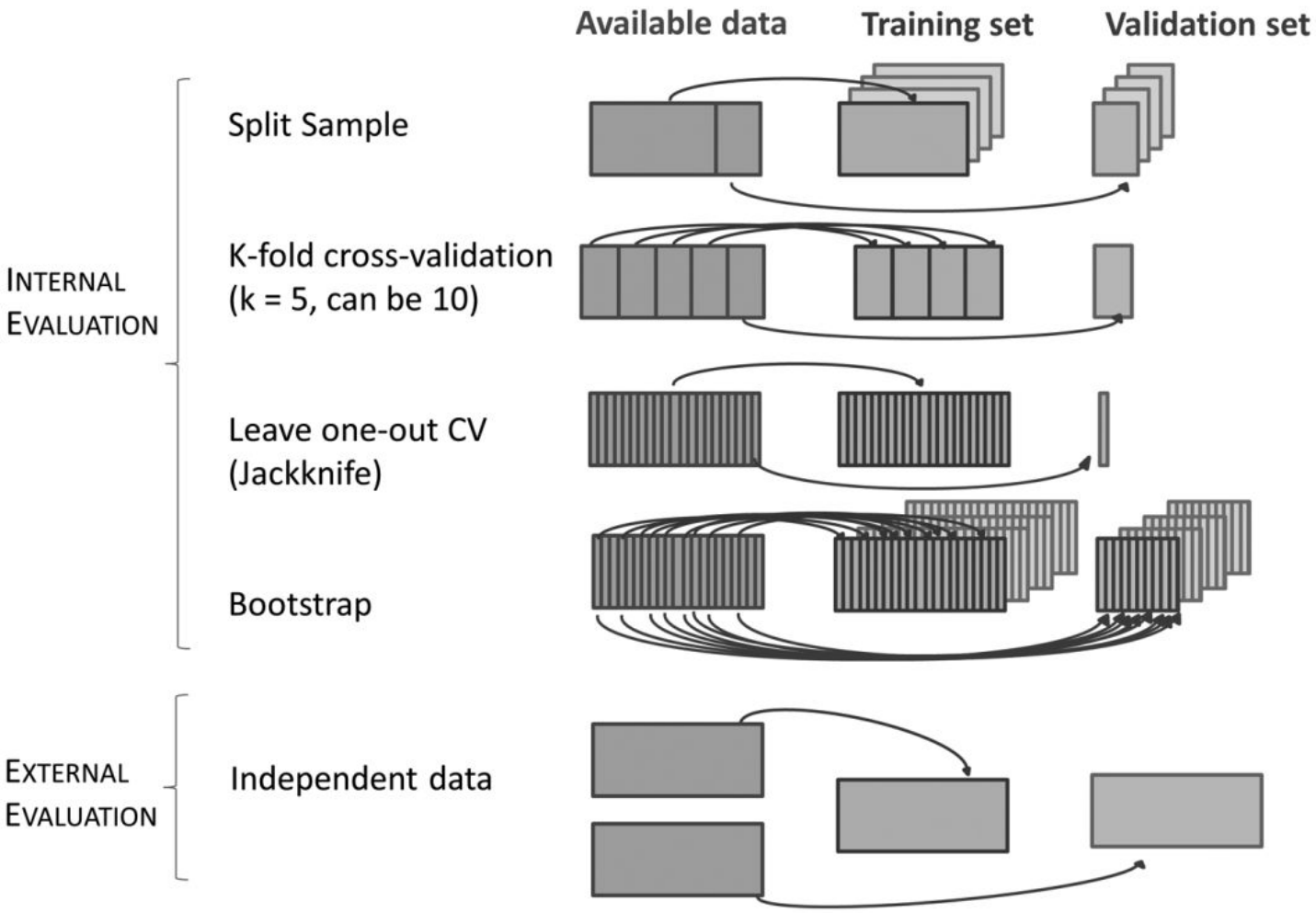


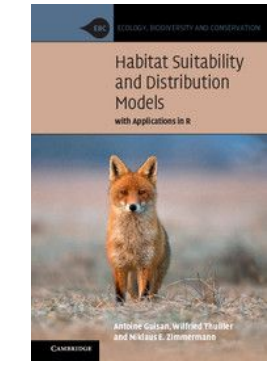
# 7. Avaliação dos modelos

Como saber se meu modelo se **aproxima da realidade**?

# Avaliação dos SDMs

## Tipos de avaliação

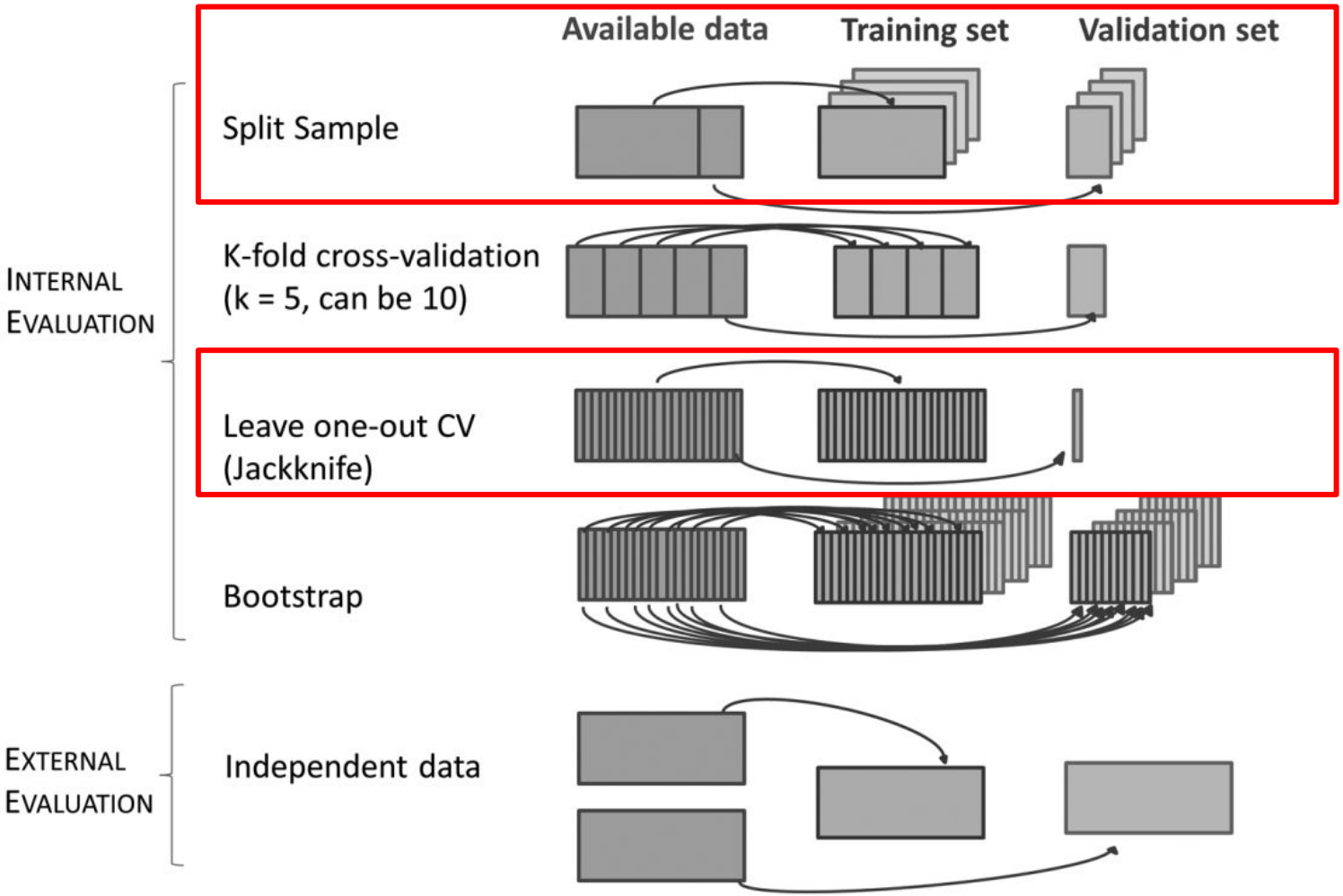


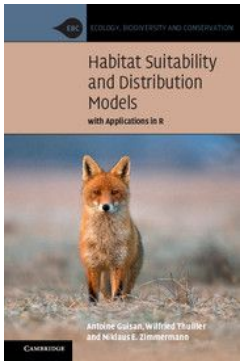




Guisan et al. (2017)

# Avaliação dos SDMs

## Tipos de avaliação

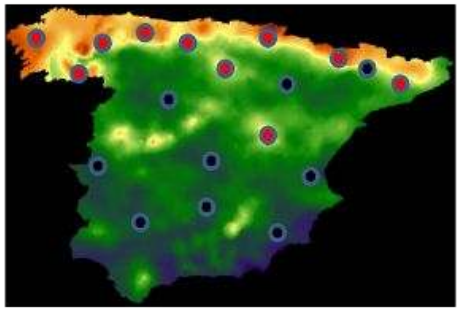


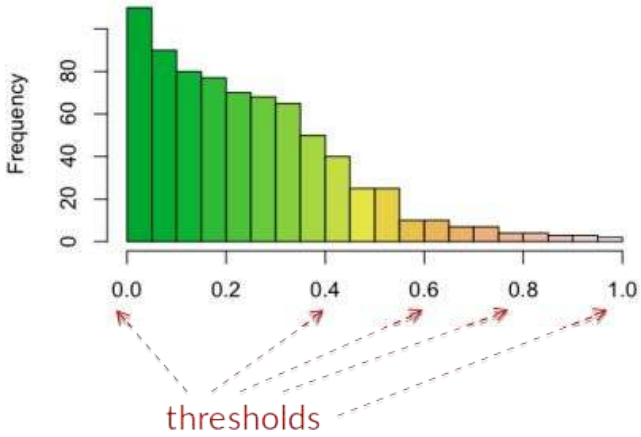



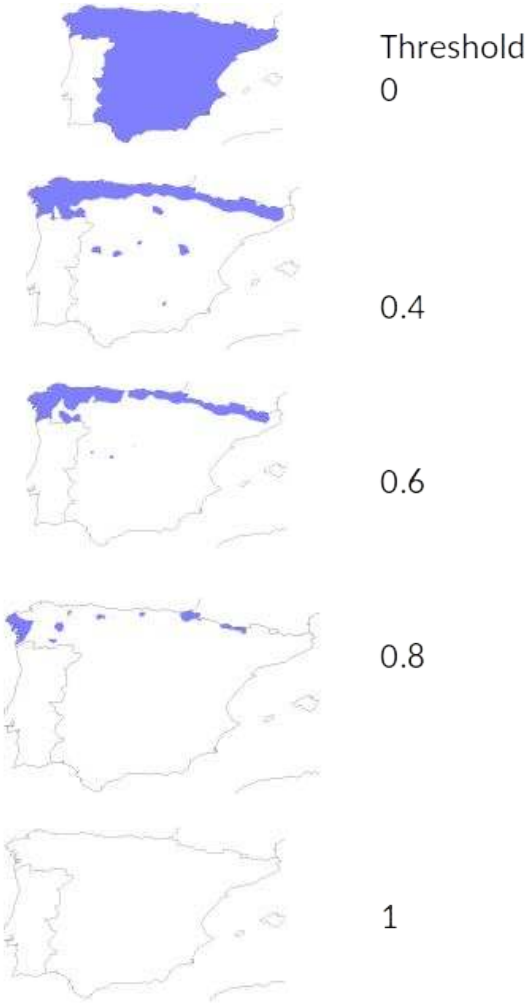

Guisan et al. (2017)

# Avaliação dos SDMs

## Limiares (*Thresholds*)

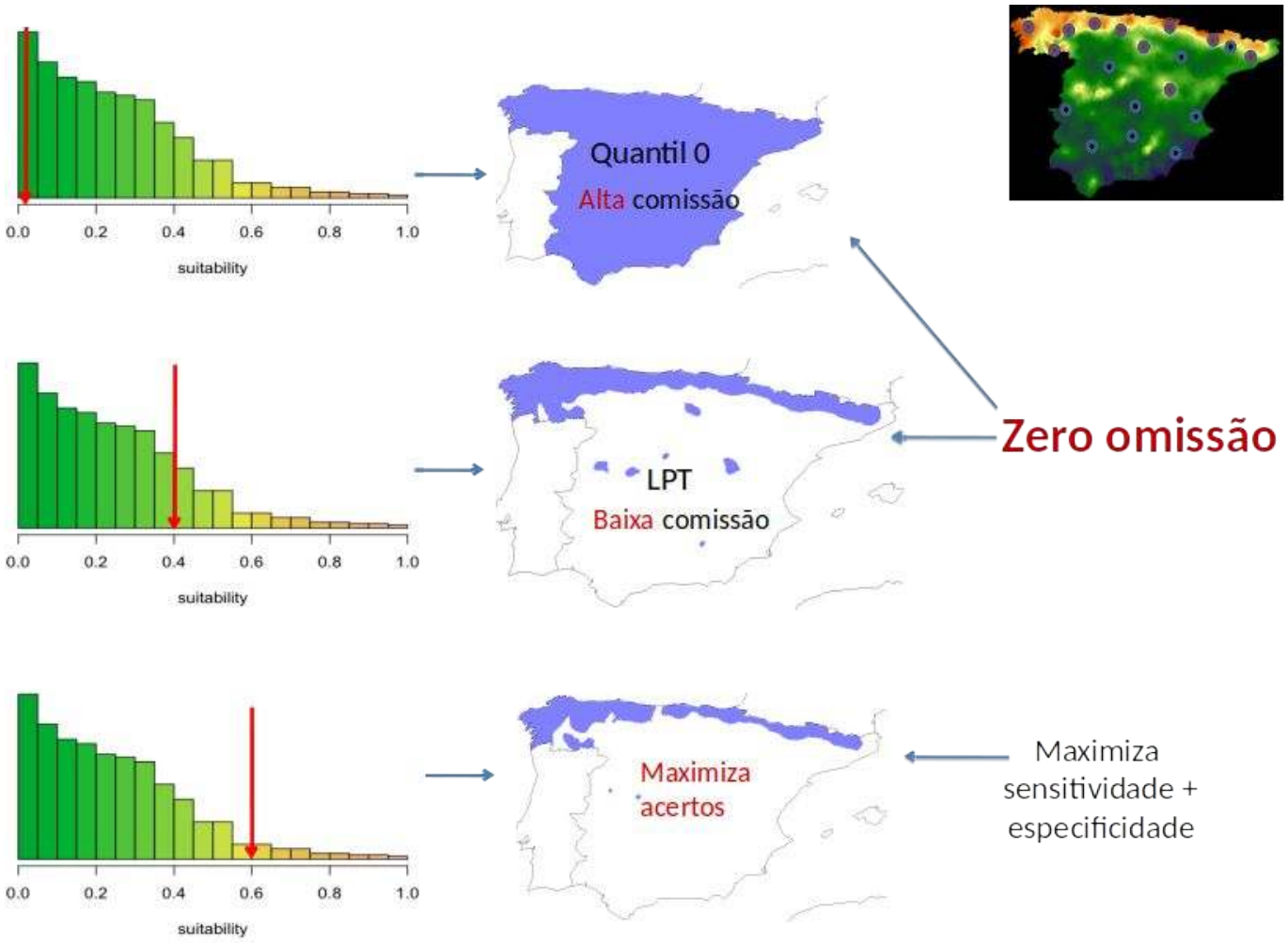




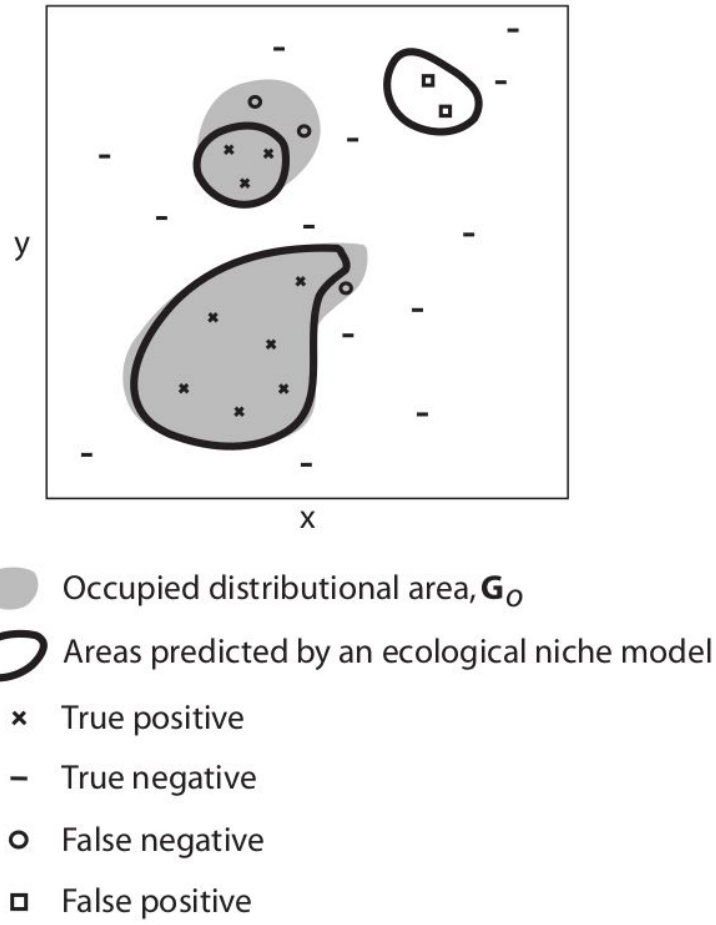
# Avaliação dos SDMs

## Limiares (*Thresholds*)



# Avaliação dos SDMs

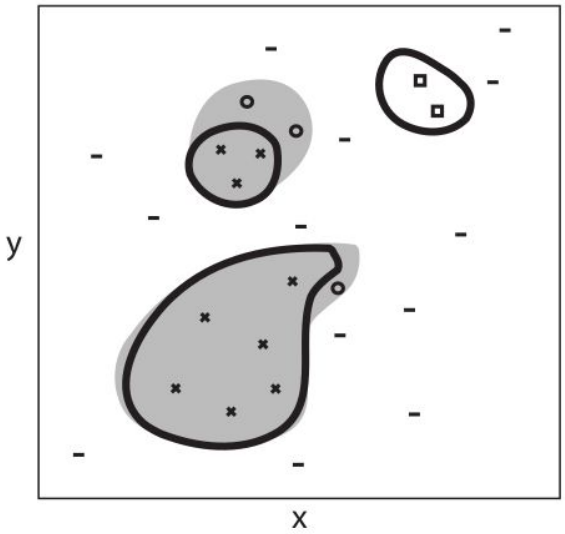
## Matriz de confusão




| | | Observation | |
|---|---|---|---|
| | | Present | Absent |
| Prediction | Present | True positive | False positive |
| | Absent | False negative | True negative |

# Avaliação dos SDMs

## Matriz de confusão

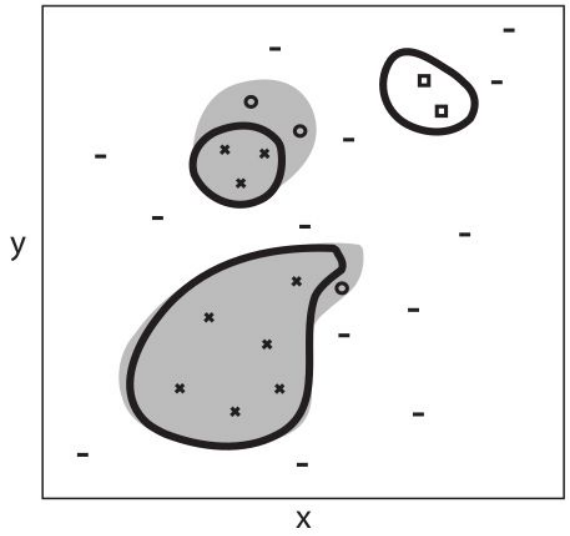



| | | Observation: Present | Observation: Absent |
|---|---|---|---|
| Prediction | Present | True positive | False positive |
| Prediction | Absent | False negative | True negative |

**Ocorrência** que o modelo previu como **presença (acerto)**

# Avaliação dos SDMs

## Matriz de confusão




Occupied distributional area, $G_O$

Areas predicted by an ecological niche model

× True positive

– True negative

o False negative

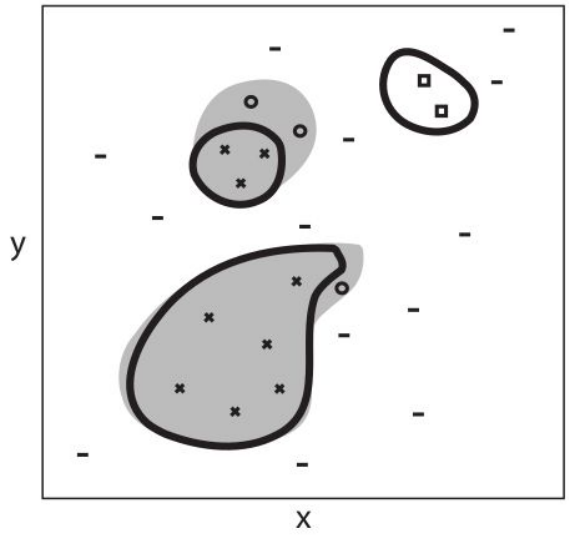
□ False positive

| | | Observation: Present | Observation: Absent |
|---|---|---|---|
| Prediction | Present | True positive | False positive |
| Prediction | Absent | False negative | True negative |

**Pseudo-ausência** que o modelo previu como **ausência (acerto)**

# Avaliação dos SDMs

## Matriz de confusão

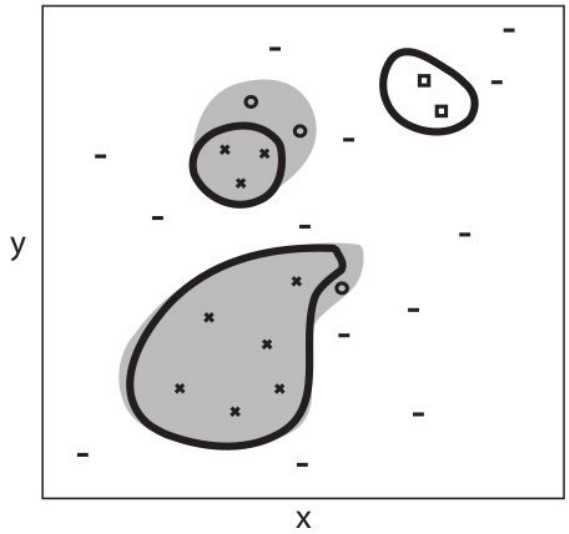



| | | Observation: Present | Observation: Absent |
|---|---|---|---|
| Prediction | Present | True positive | False positive |
| Prediction | Absent | False negative | True negative |

**Ocorrência** que o modelo previu como **ausência (erro de omissão)**

# Avaliação dos SDMs

## Matriz de confusão

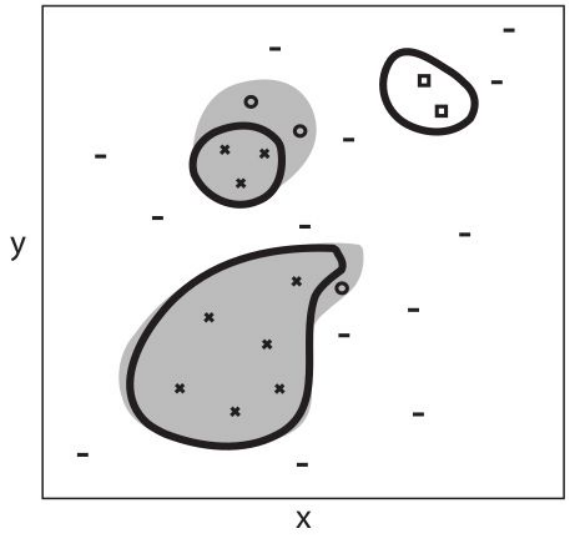



| | | Observation | |
|---|---|---|---|
| | | Present | Absent |
| Prediction | Present | True positive | False positive |
| | Absent | False negative | True negative |

**Pseudo-ausência** que o modelo previu como **presença (erro de comissão)**

# Avaliação dos SDMs

## Matriz de confusão




Occupied distributional area, $G_O$

Areas predicted by an ecological niche model

× True positive

– True negative

o False negative

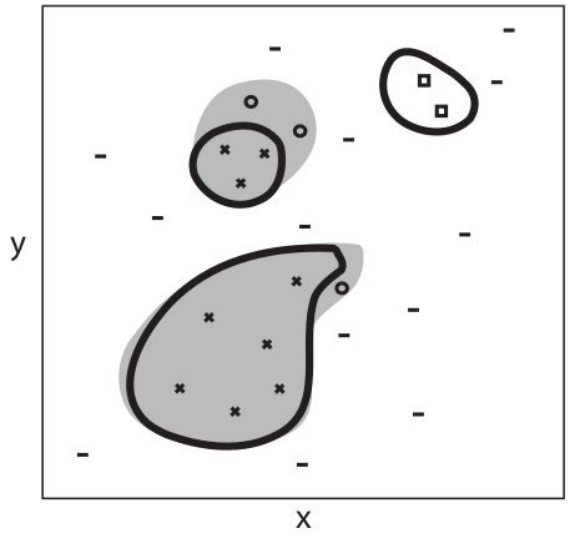
□ False positive

| | | Observation: Present | Observation: Absent |
|---|---|---|---|
| Prediction | Present | True positive | False positive |
| Prediction | Absent | False negative | True negative |

**Sensitividade: presenças corretas / total de presenças**

# Avaliação dos SDMs

## Matriz de confusão




Occupied distributional area, $G_O$

Areas predicted by an ecological niche model

× True positive

– True negative

o False negative

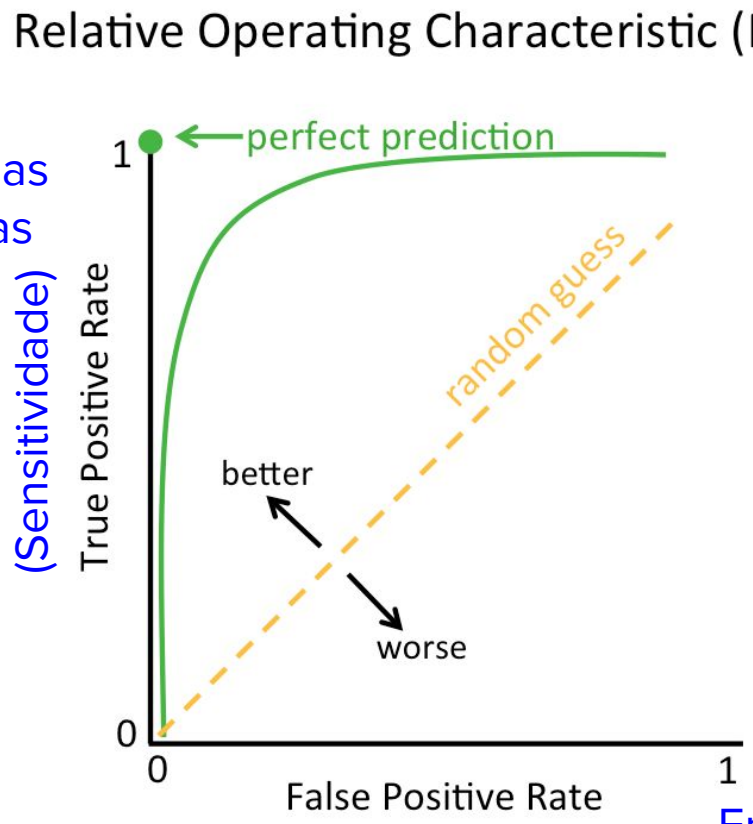
□ False positive

| | | Observation: Present | Observation: Absent |
|---|---|---|---|
| Prediction | Present | True positive | False positive |
| Prediction | Absent | False negative | True negative |

**Especificidade: pseudo-ausências corretas / total de pseudo-ausências**

# Avaliação dos SDMs

## Curva ROC e AUC




Acertos das presenças

(Sensitividade)

(Especificidade - 1)

Erro das ausências

AUC = area under the curve

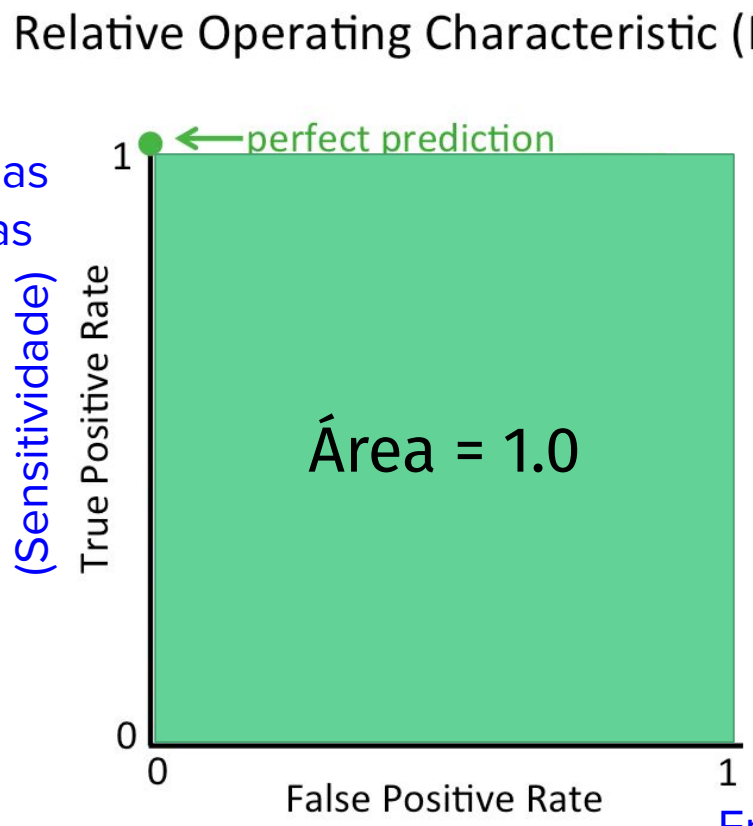
0.5-0.7 = poor model performance

0.7-0.9 = moderate

> 0.9 = excellent

# Avaliação dos SDMs

## Curva ROC e AUC




Acertos das presenças (Sensitividade)

Erro das ausências (Especificidade - 1)

AUC = area under the curve

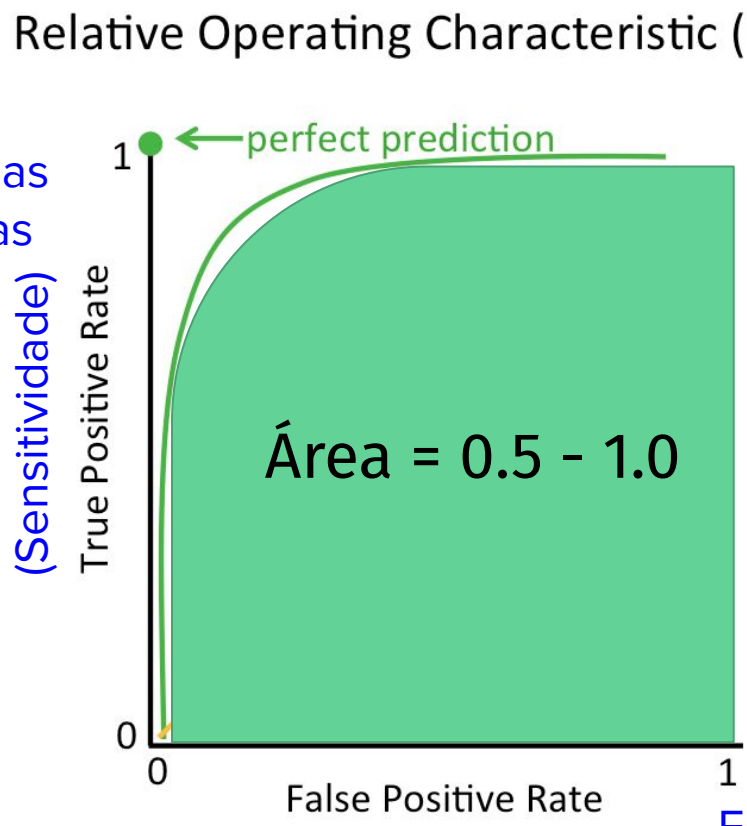
0.5-0.7 = poor model performance

0.7-0.9 = moderate

> 0.9 = excellent

# Avaliação dos SDMs

## Curva ROC e AUC




Acertos das presenças (Sensitividade)

(Especificidade - 1) Erro das ausências

AUC = area under the curve

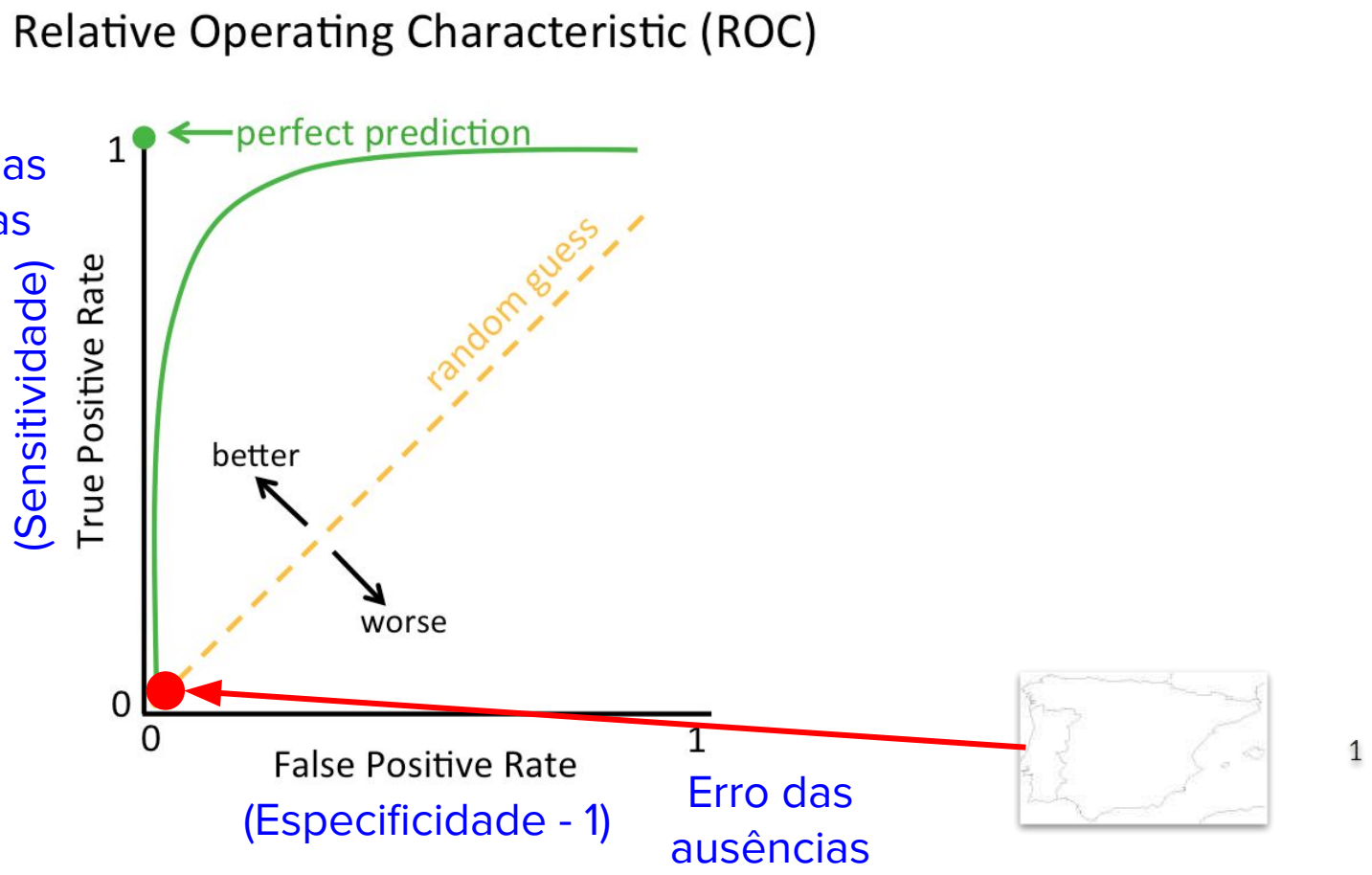
0.5-0.7 = poor model performance

0.7-0.9 = moderate

> 0.9 = excellent

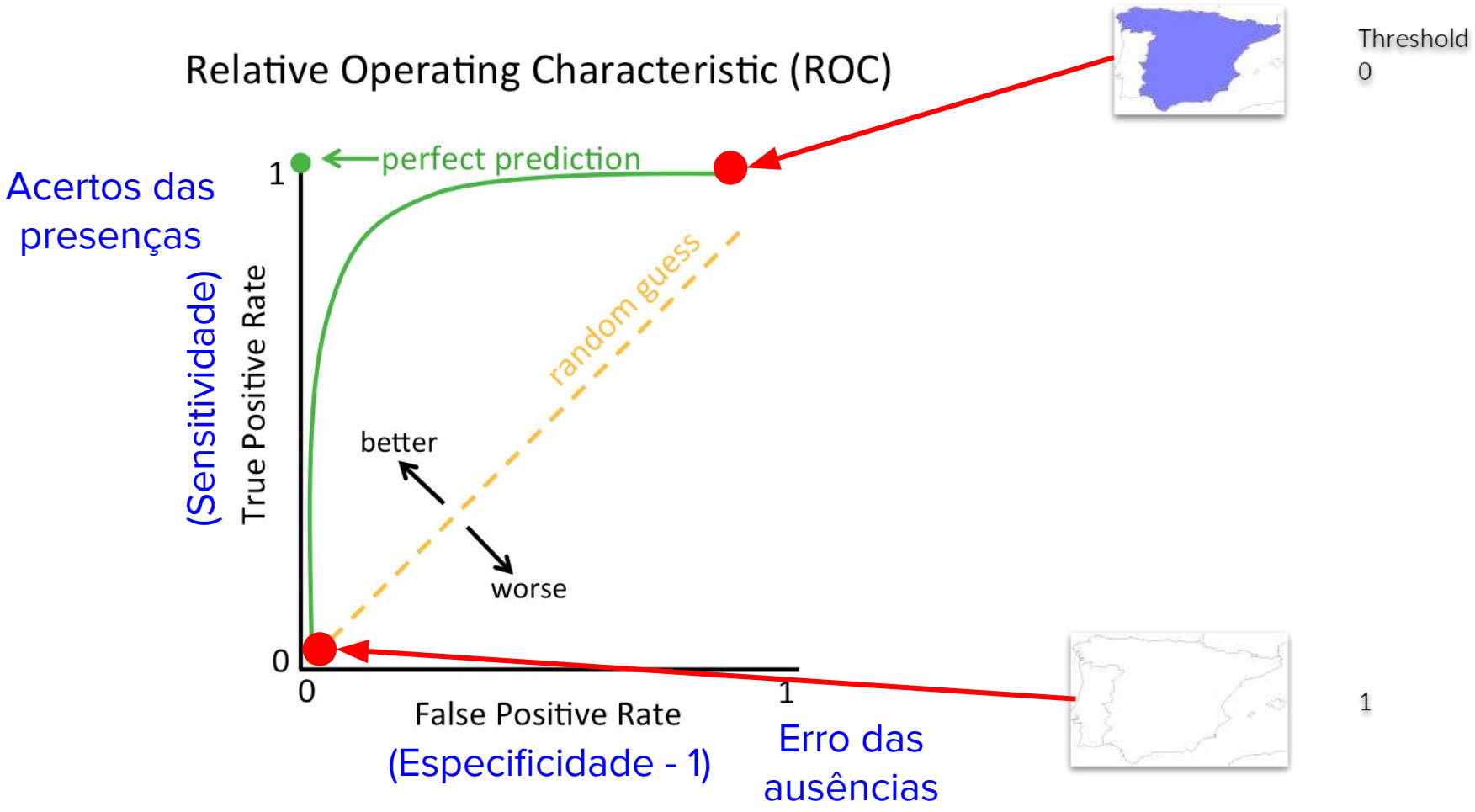
# Avaliação dos SDMs

## Curva ROC e AUC



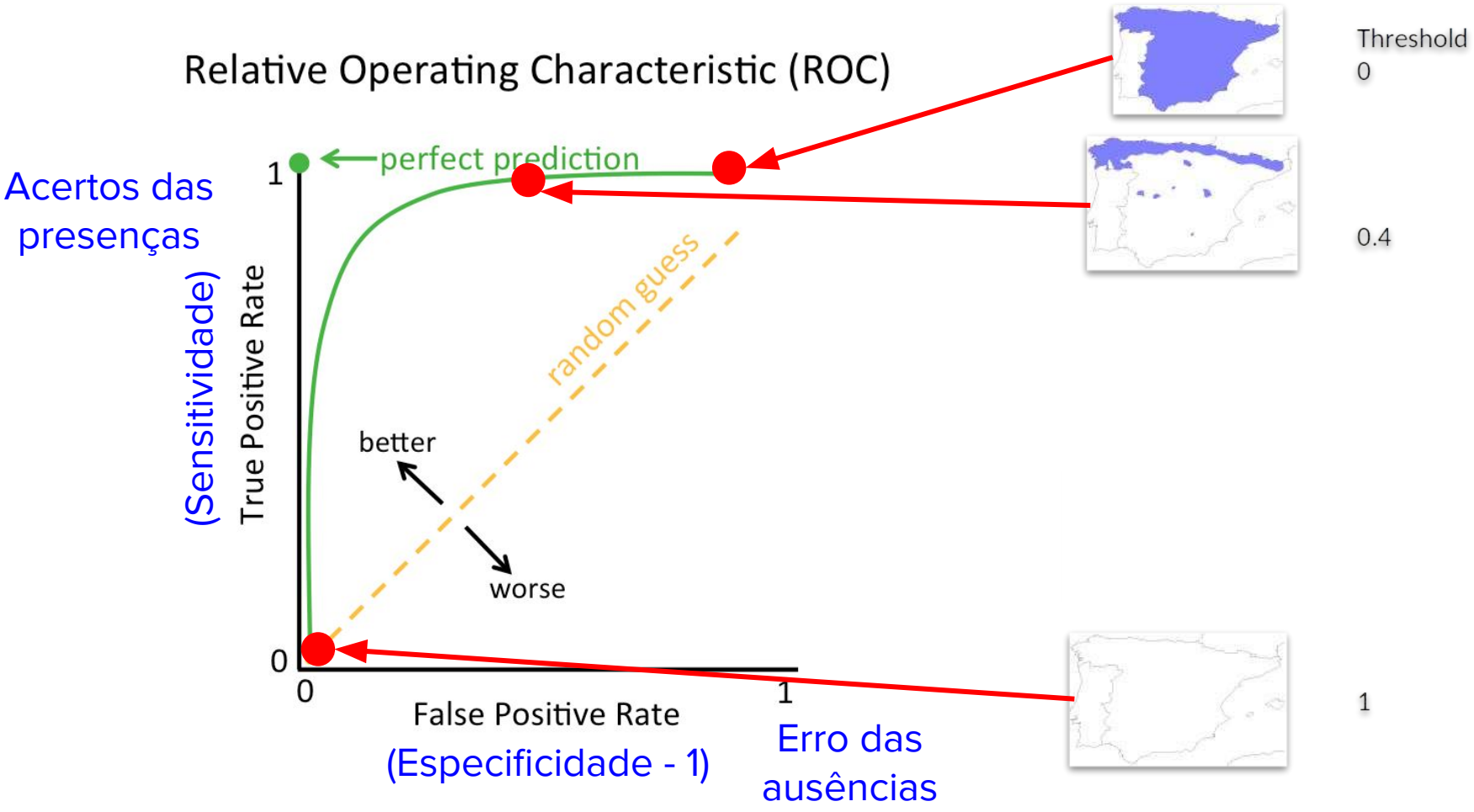
# Avaliação dos SDMs

## Curva ROC e AUC



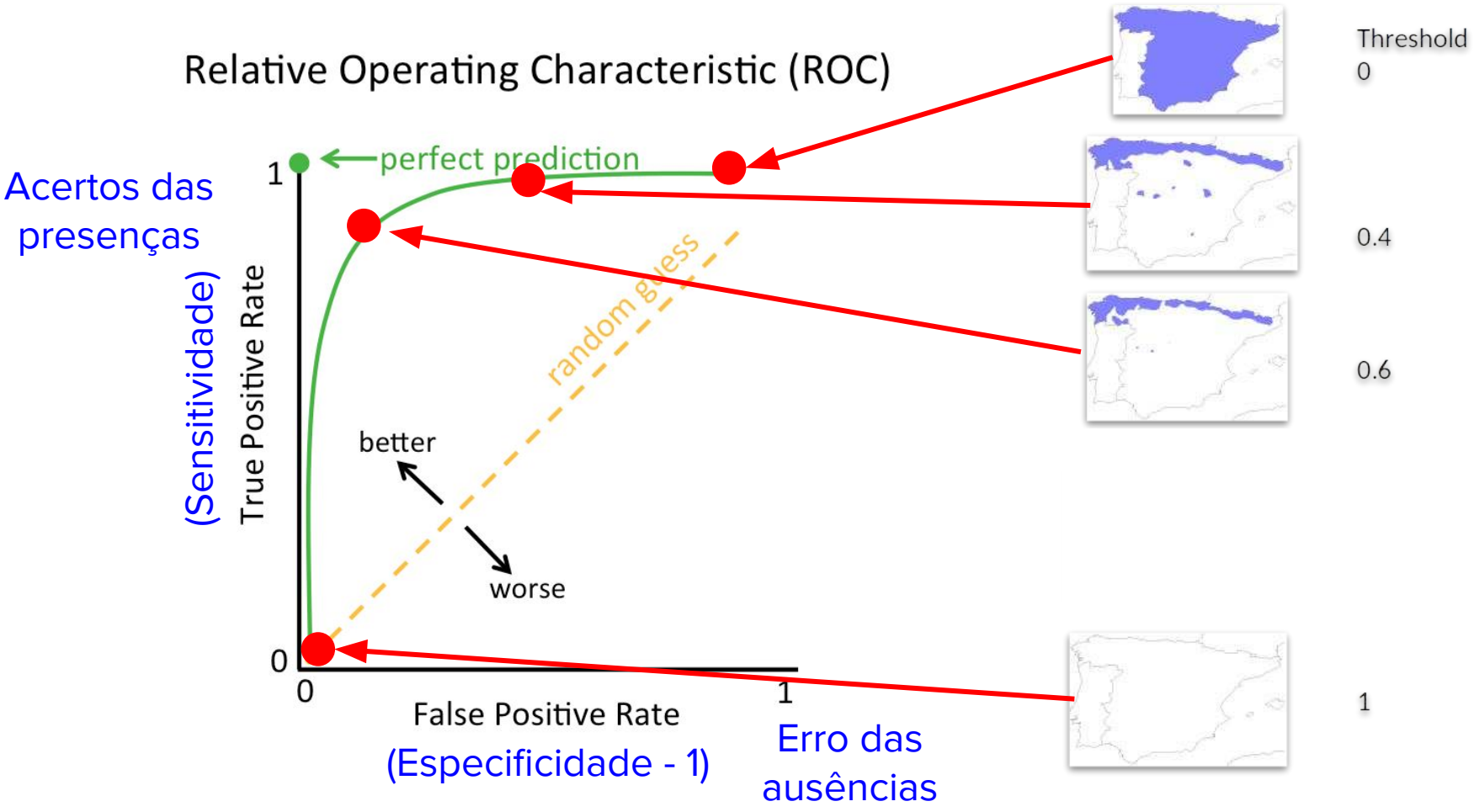
# Avaliação dos SDMs

## Curva ROC e AUC



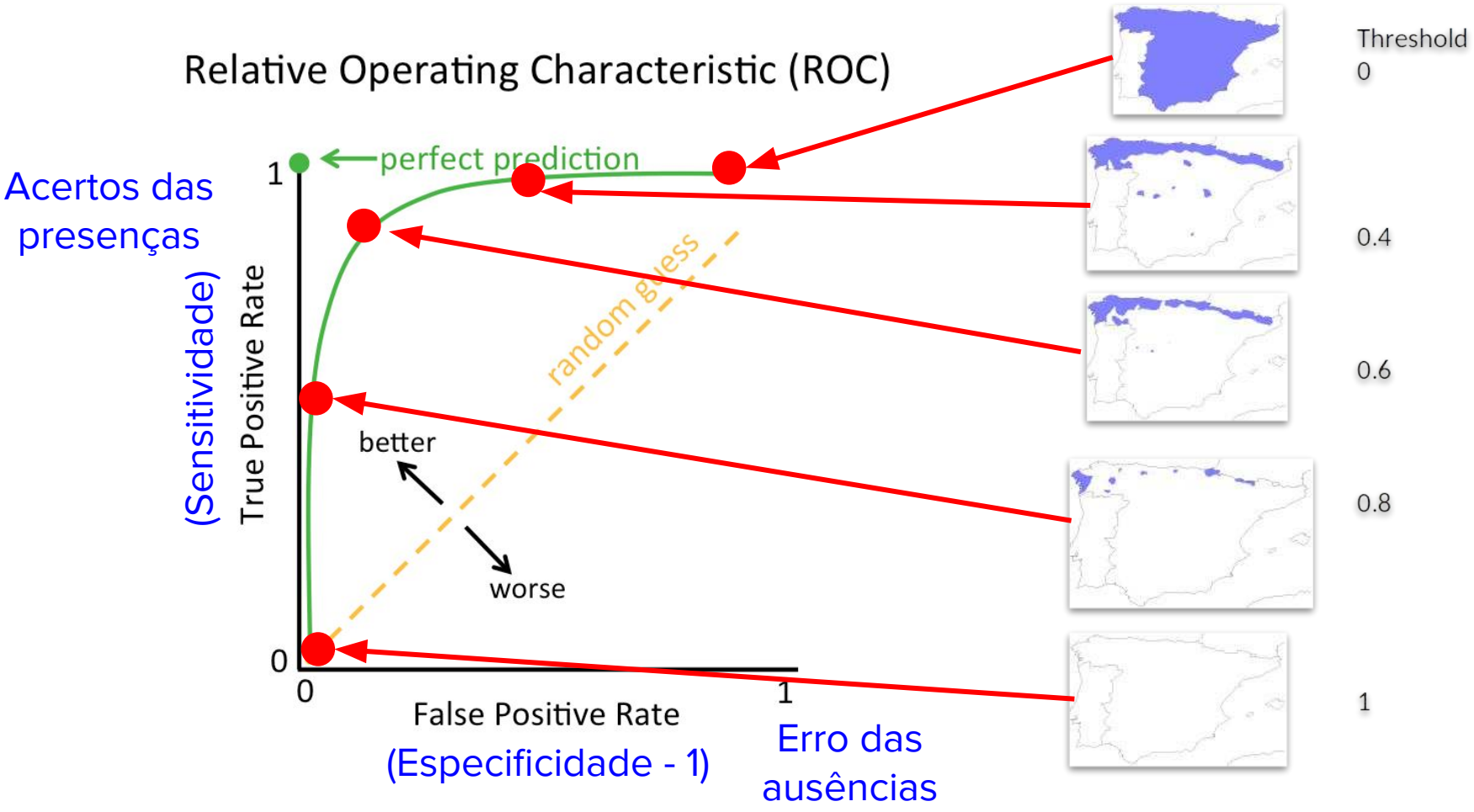
# Avaliação dos SDMs

## Curva ROC e AUC



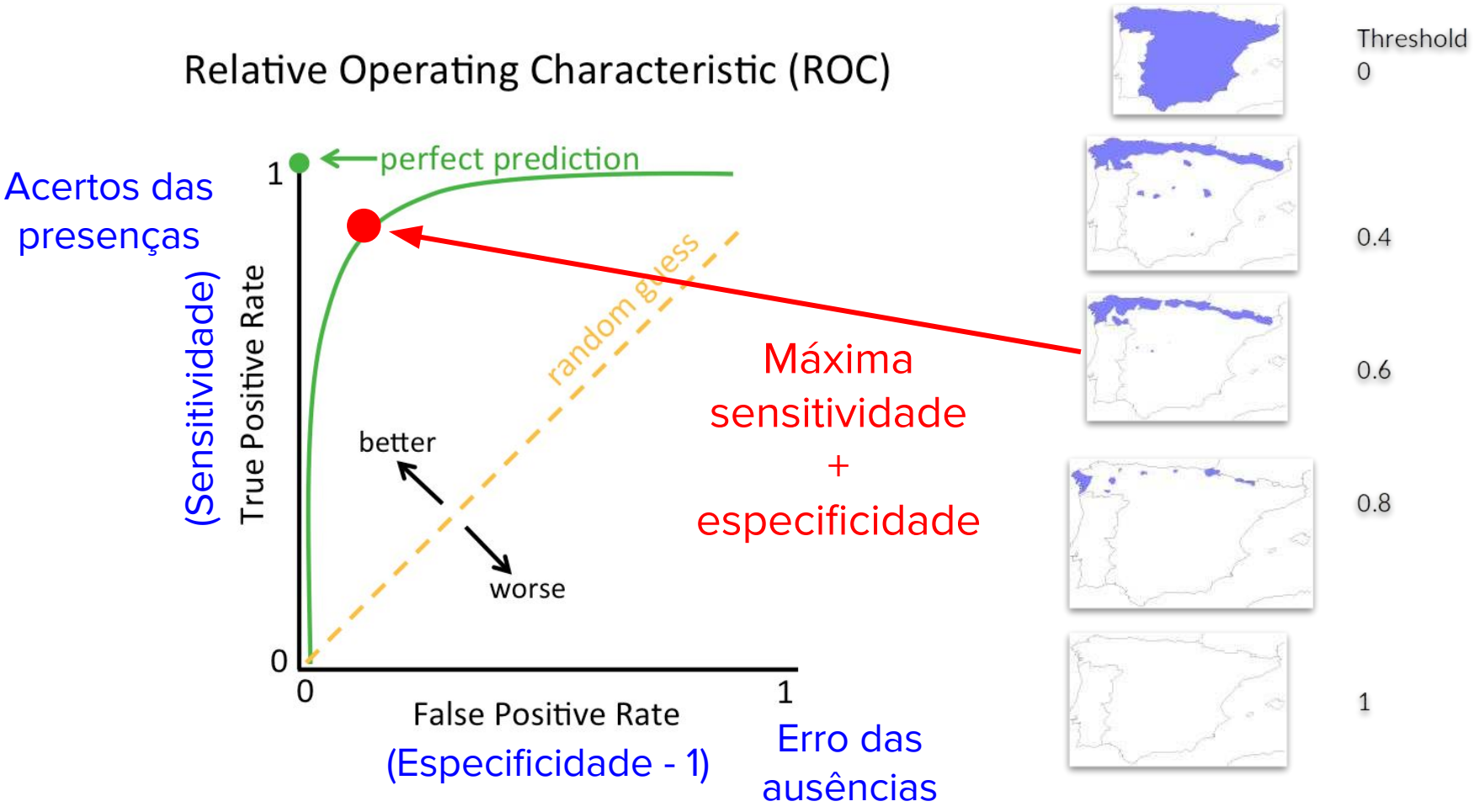
# Avaliação dos SDMs

## Curva ROC e AUC



# Avaliação dos SDMs

## Curva ROC e AUC



# Avaliação dos SDMs

## TSS (*True skill statistic*)

Número de sucessos menos o número de sucessos aleatórios

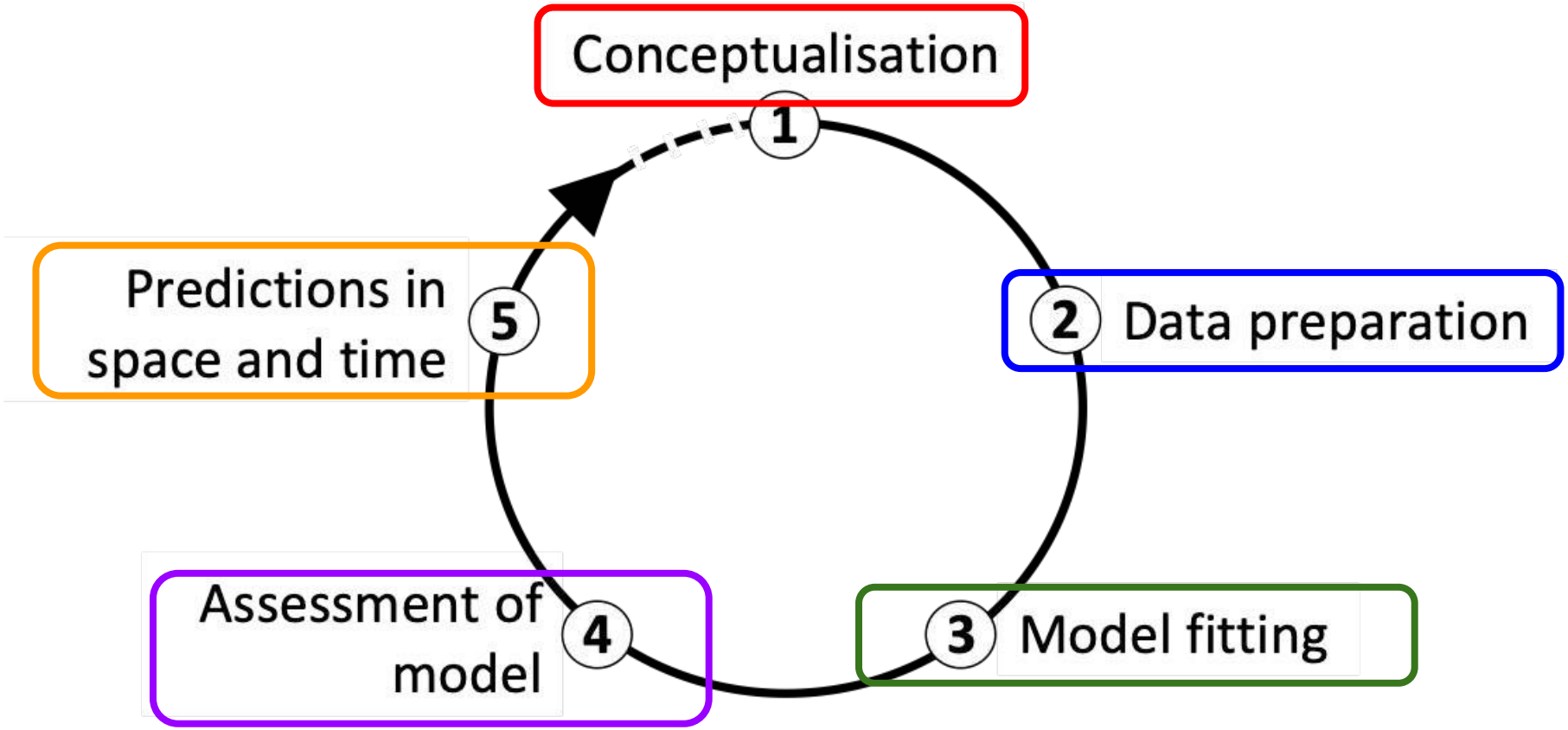
Varia de -1 to 1. Valores  próximos a 0 modelos não diferentes do aleatórios

Depende de um valor de corte (threshold)

**TSS = sensitividade + especificidade - 1**

# SDM passo a passo

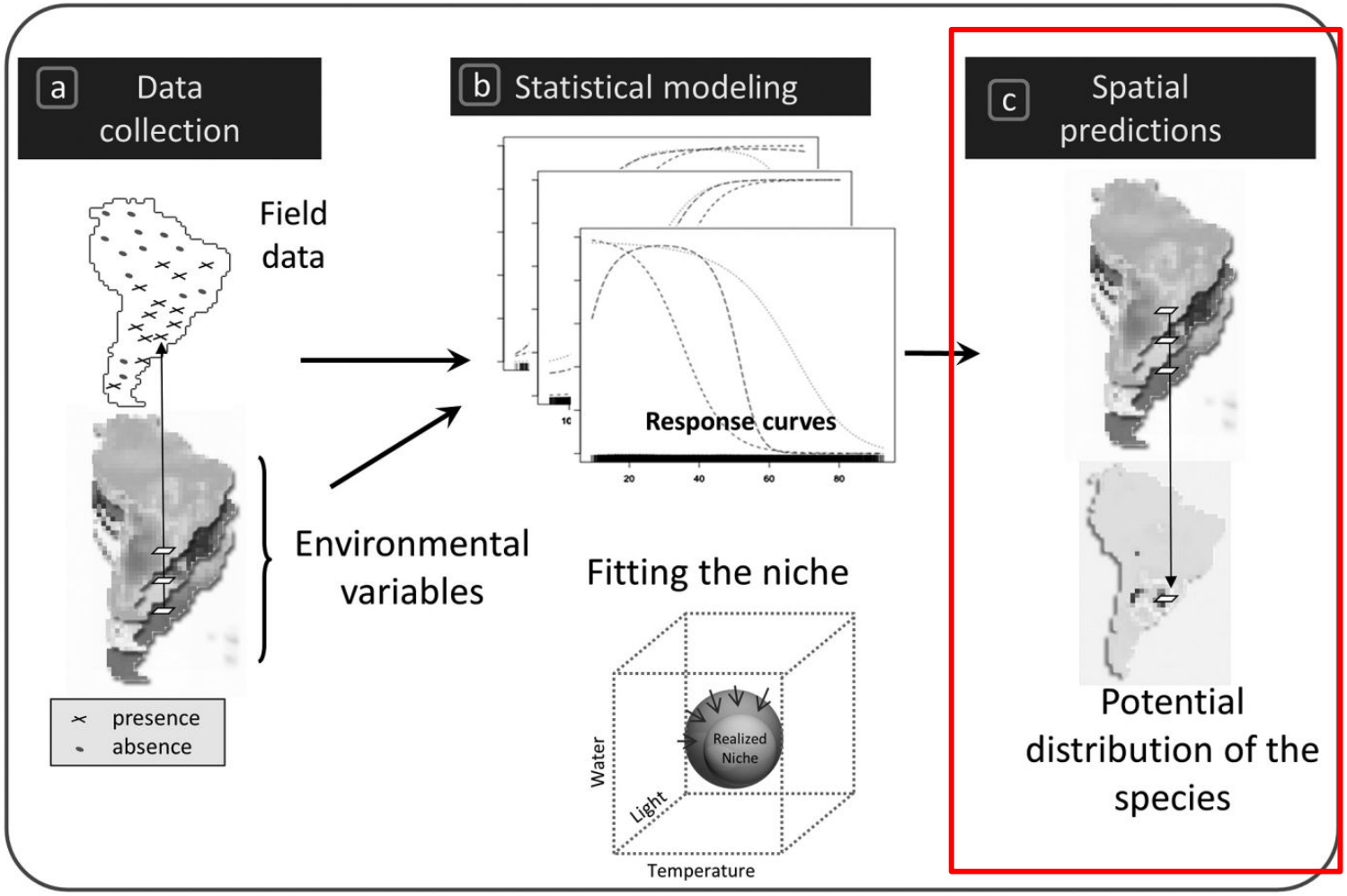
## Estrutura dos SDMs

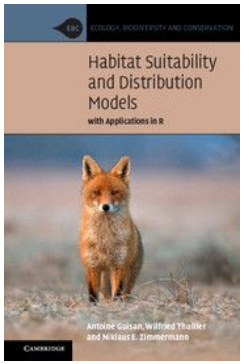


# 8. Predições no espaço e no tempo

# Modelos de Distribuição de Espécies (SDMs)

## Predições (espaço e no tempo)

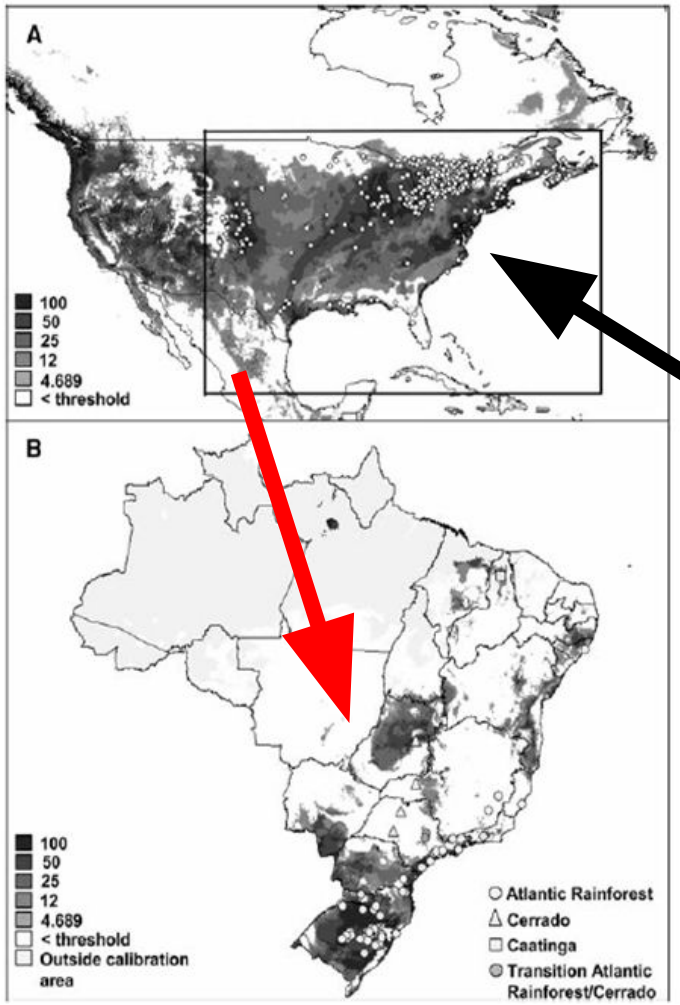



Guisan et al. (2017)

# Modelos de Distribuição de Espécies (SDMs)

## Espaço - Espécies invasoras




Biol Invasions
DOI 10.1007/s10530-007-9154-5

ORIGINAL PAPER

**Predicting the potential distribution of the alien invasive American bullfrog (*Lithobates catesbeianus*) in Brazil**

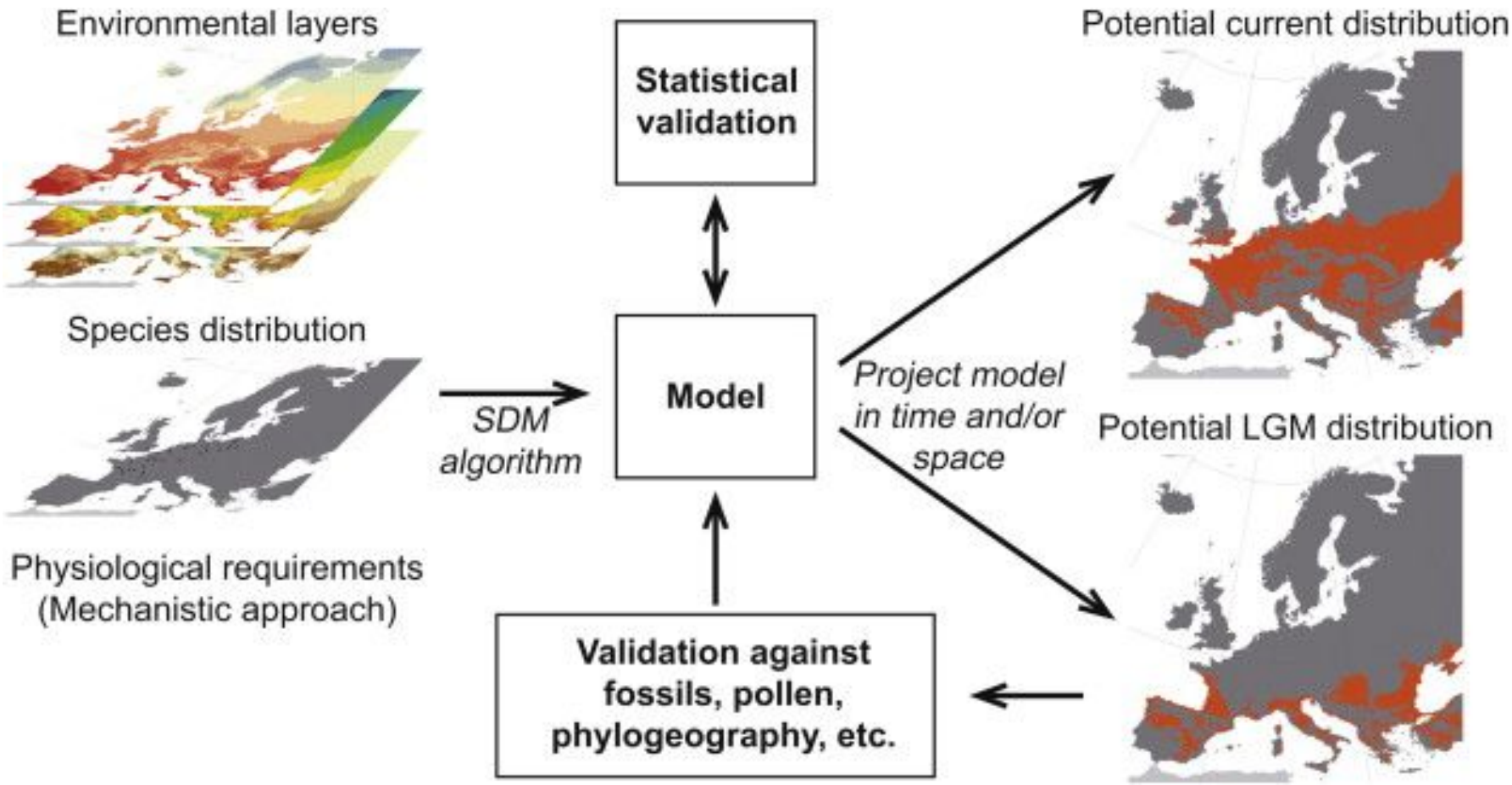
João G. R. Giovanelli · Célio F. B. Haddad · João Alexandrino

Foto: Carl D. Howe

*Giovanelli et al., 2008. Biological Invasions*

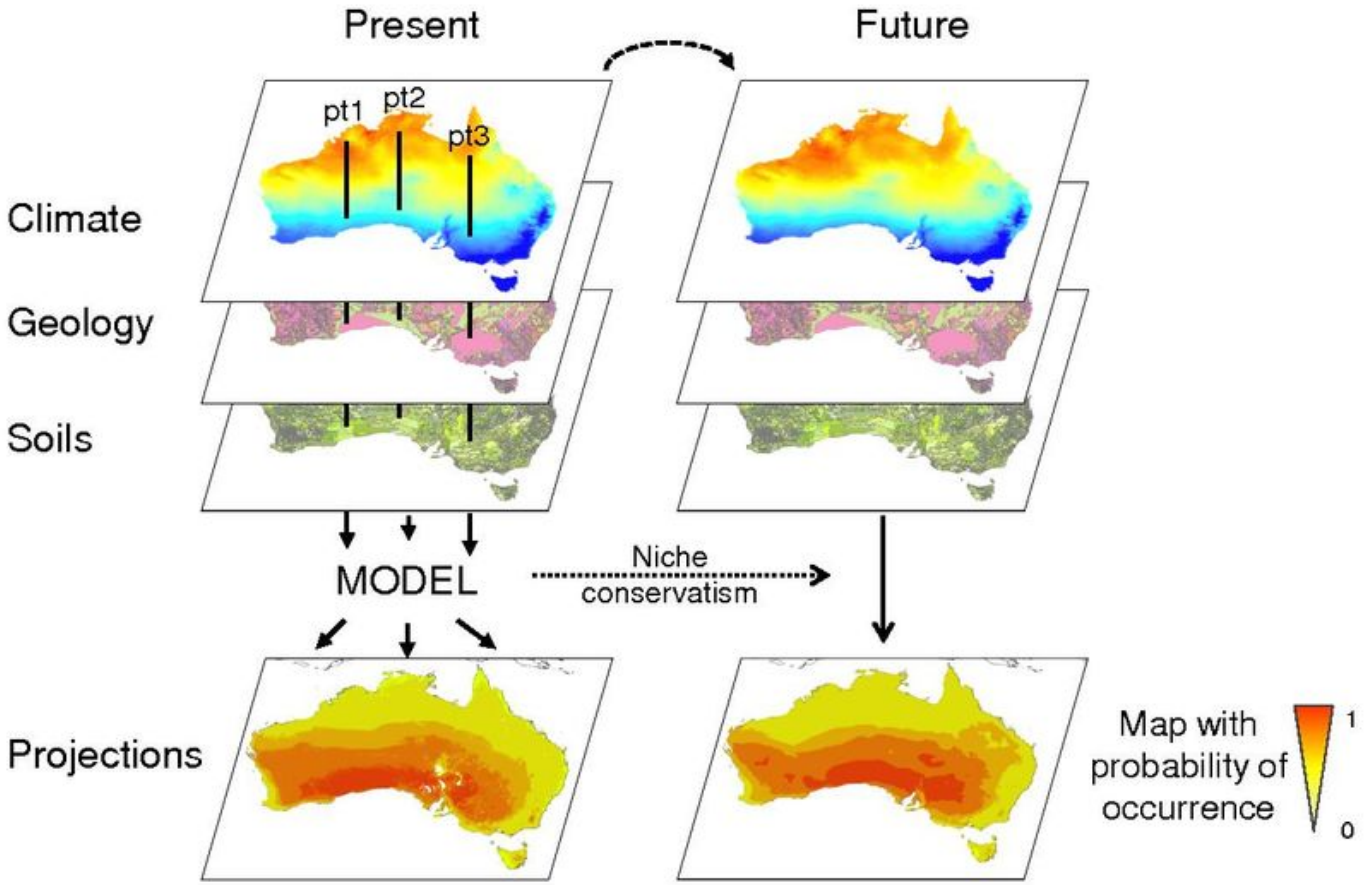
# Modelos de Distribuição de Espécies (SDMs)

## Tempo - passado



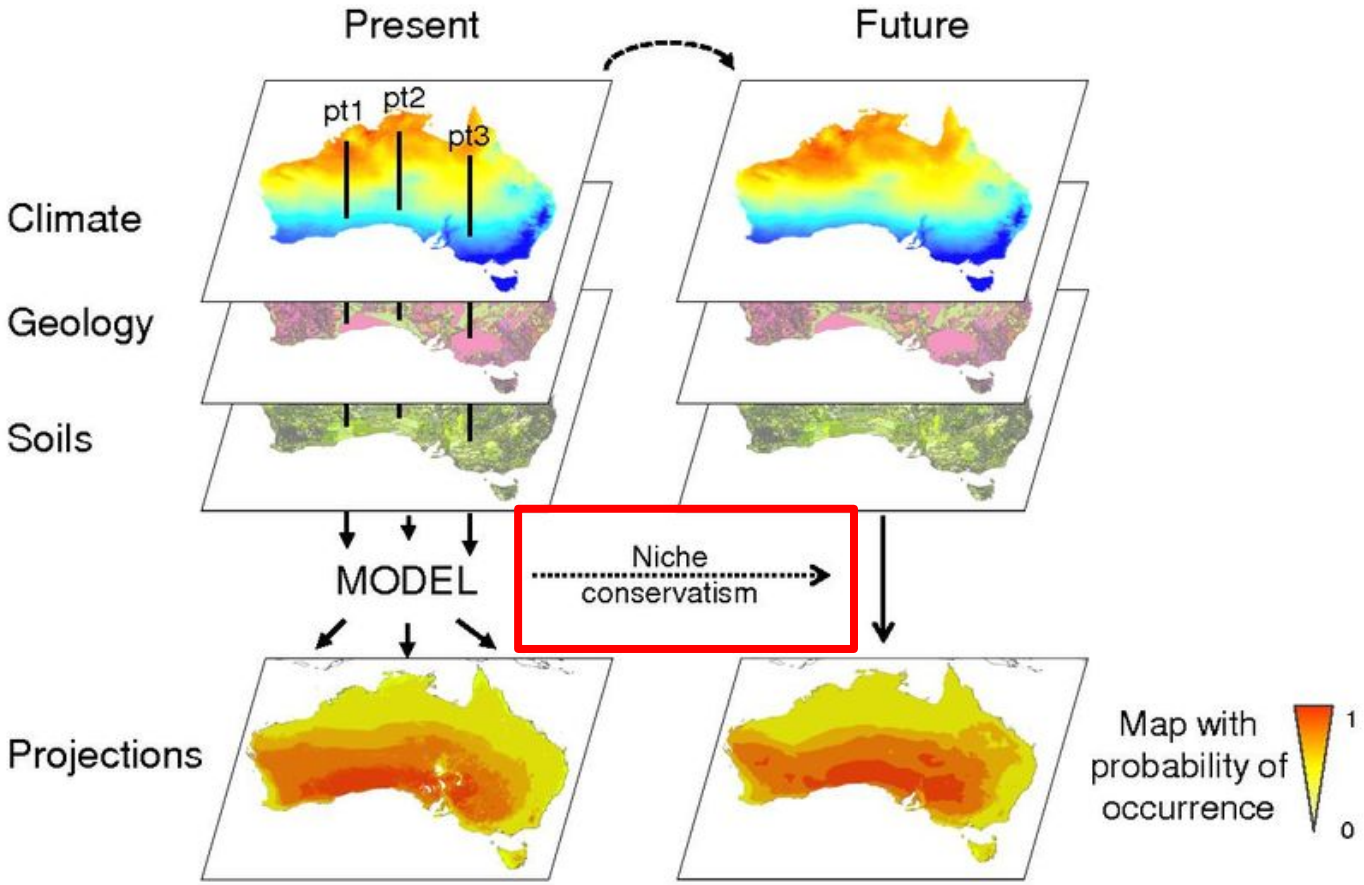
# Modelos de Distribuição de Espécies (SDMs)

## Tempo - futuro



# Modelos de Distribuição de Espécies (SDMs)

## Tempo - futuro

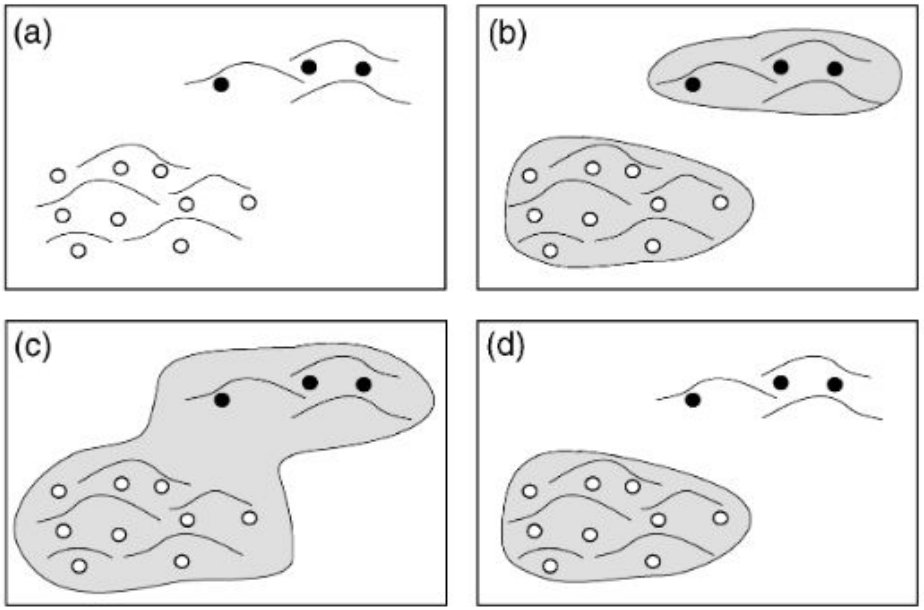


# Modelos de Distribuição de Espécies (SDMs)

## Premissa - Conservação de nicho

**NICHE CONSERVATISM: Integrating Evolution, Ecology, and Conservation Biology**

John J. Wiens and Catherine H. Graham
*Department of Ecology and Evolution, Stony Brook University, Stony Brook, New York 11794-5245; email: wiensj@life.bio.sunysb.edu, cgraham@life.bio.sunysb.edu*



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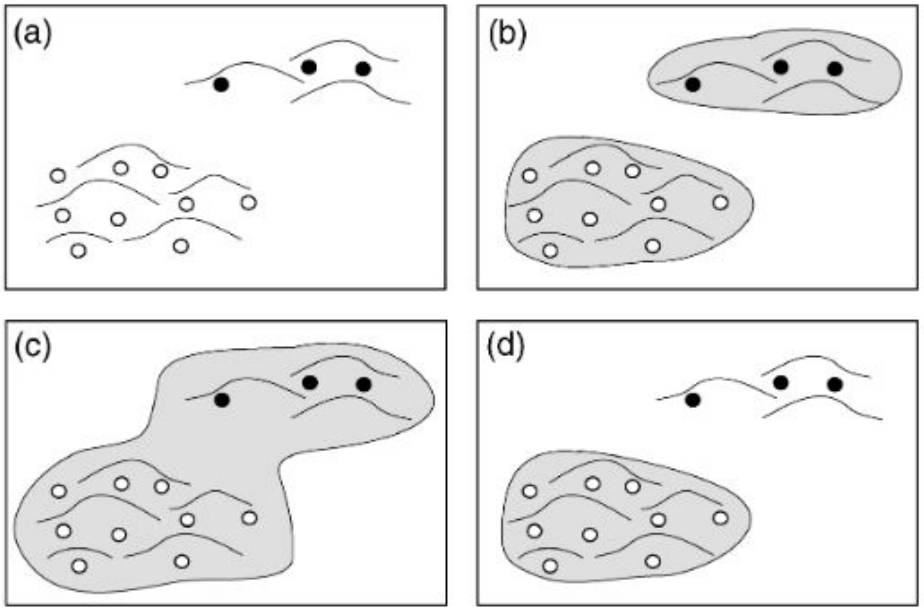


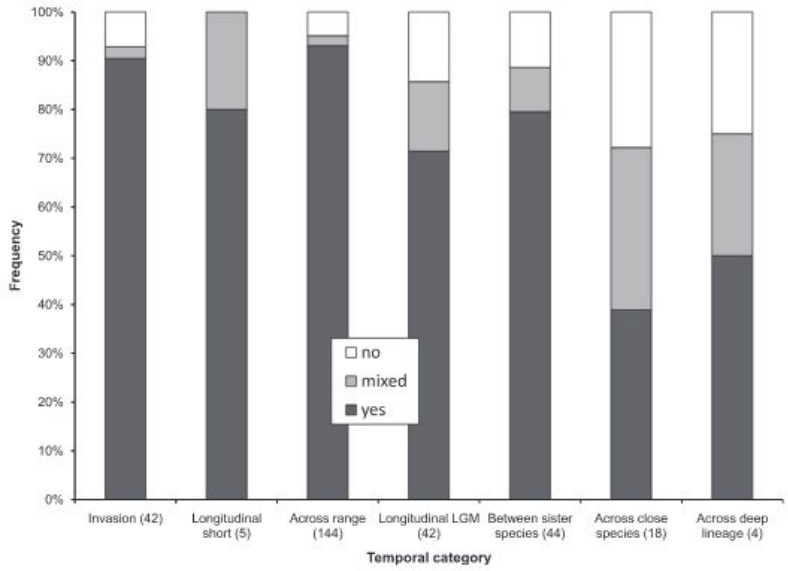

Journal of Biogeography

SYNTHESIS | Free Access

**Ecological niche conservatism: a time-structured review of evidence**

A. Townsend Peterson

First published:17 March 2011 | https://doi.org/10.1111/j.1365-2699.2010.02456.x | Citations: 325



# Modelos de Distribuição de Espécies (SDMs)

## Premissa - Conservação de nicho

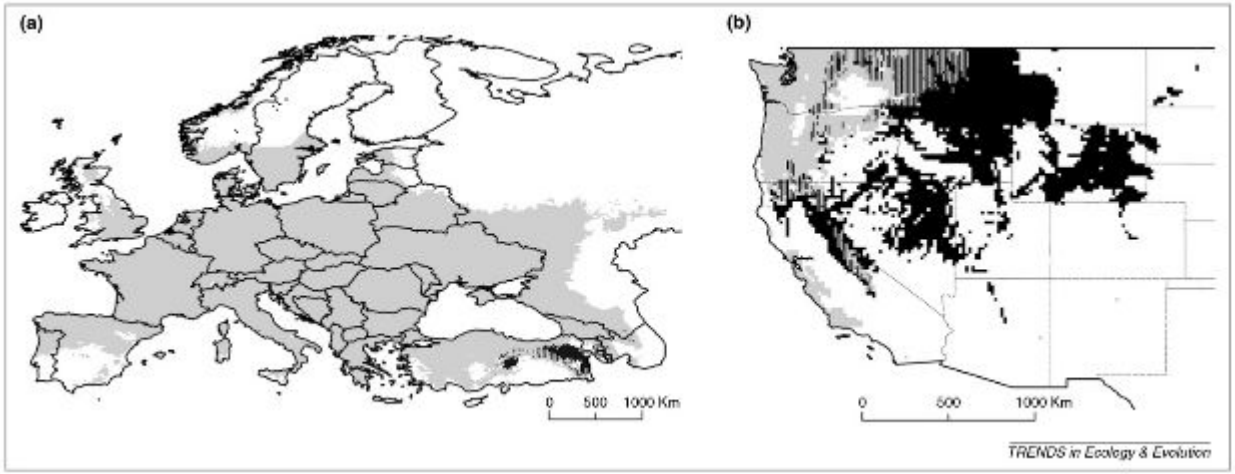
Review

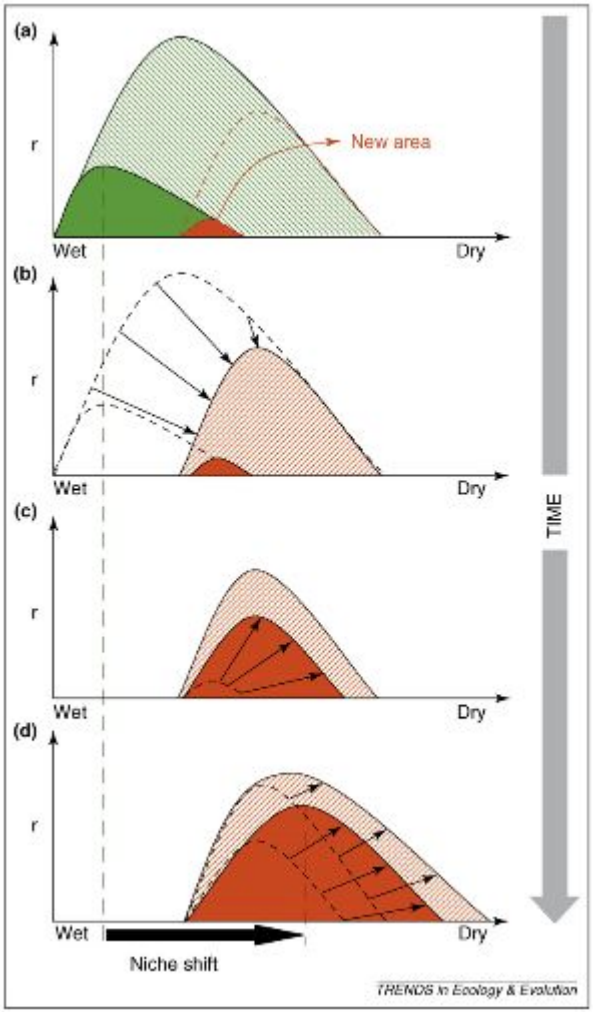
Cell PRESS

**Niche dynamics in space and time**

**Peter B. Pearman*, Antoine Guisan*, Olivier Broennimann and Christophe F. Randin**

University of Lausanne, Department of Ecology and Evolution, CH-1015 Lausanne, Switzerland



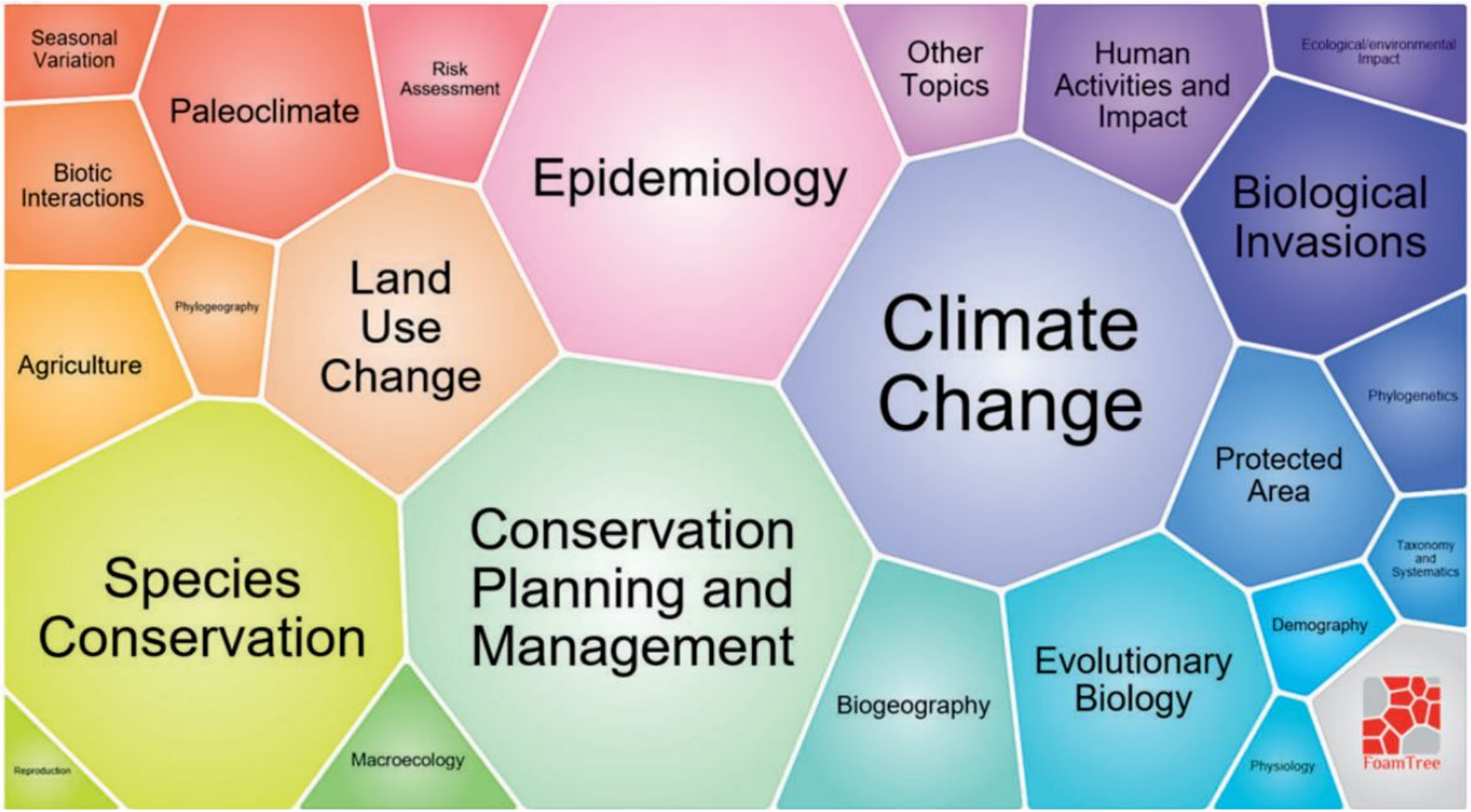



# 9. Aplicações e mais informações

# Aplicações

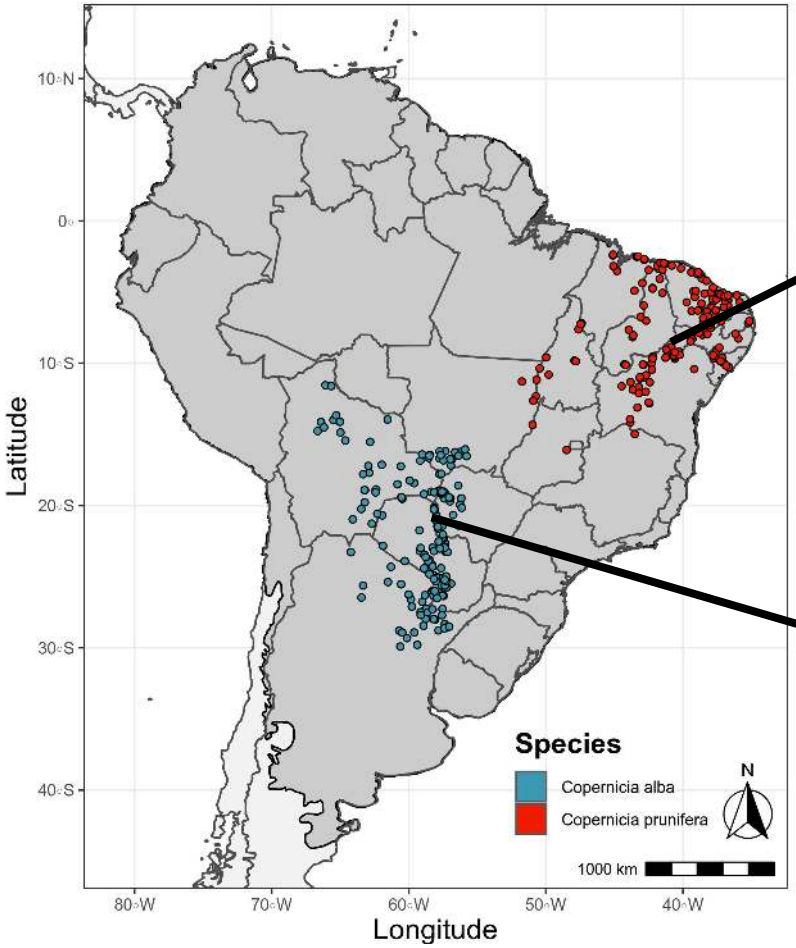
## Áreas de aplicação

Urbina-Cardona, N. et al. "Species Distribution Modeling in Latin America: A 25-Year Retrospective Review." *Tropical Conservation Science* 12 (2019).



# Aplicações

## Mudanças climáticas sobre carnaúbas

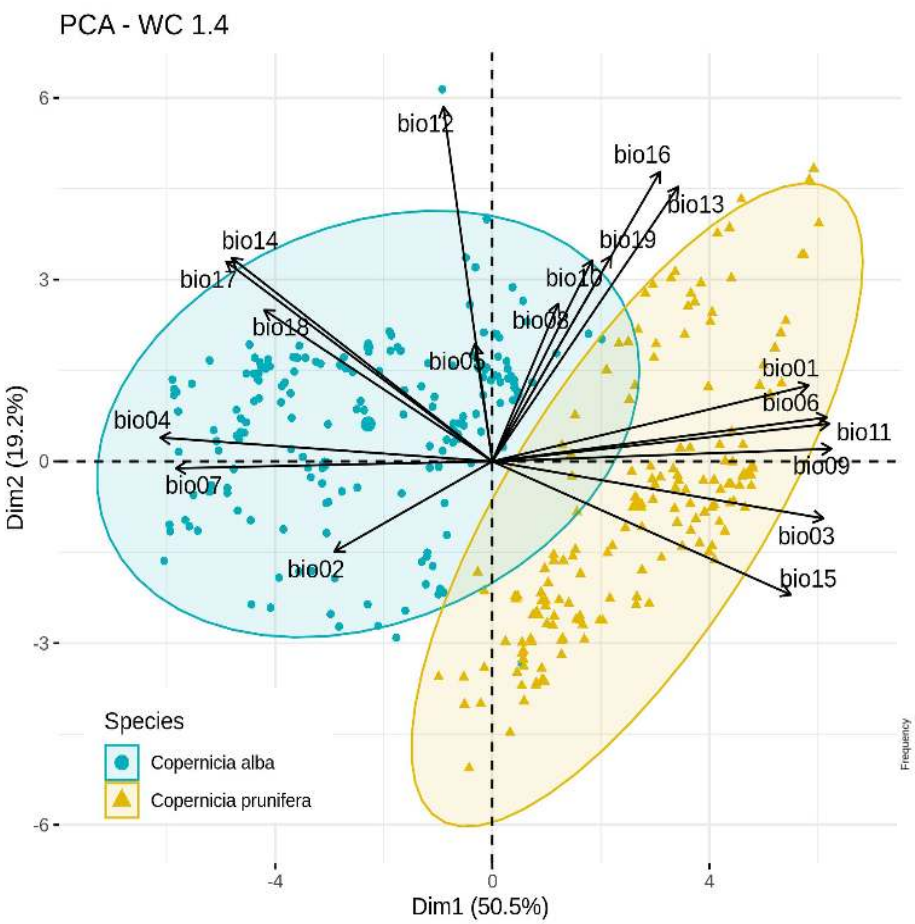


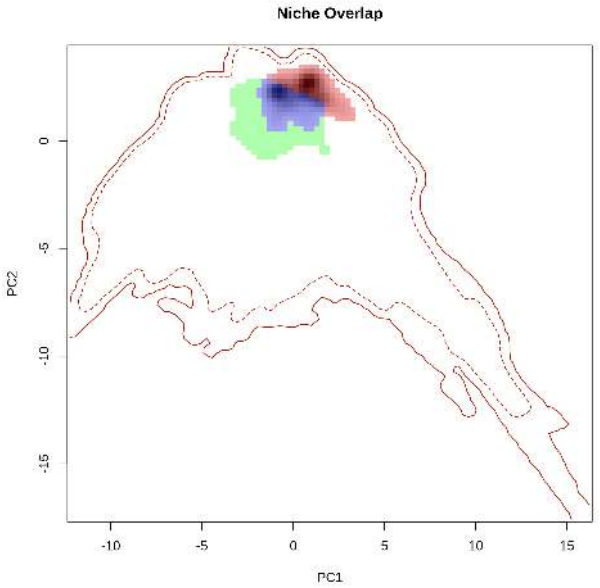

*Copernicia prunifera*

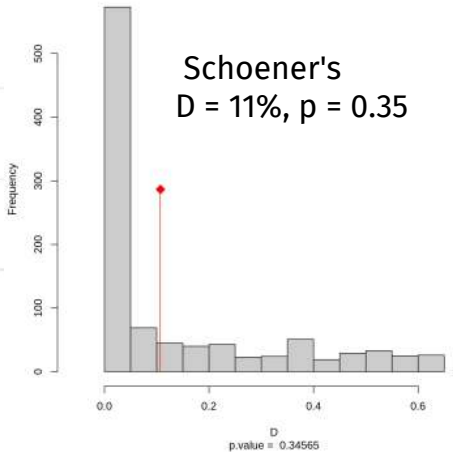
*Copernicia alba*

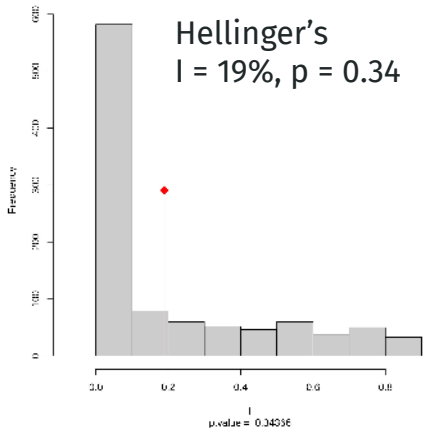
# Aplicações

## Mudanças climáticas sobre carnaúbas



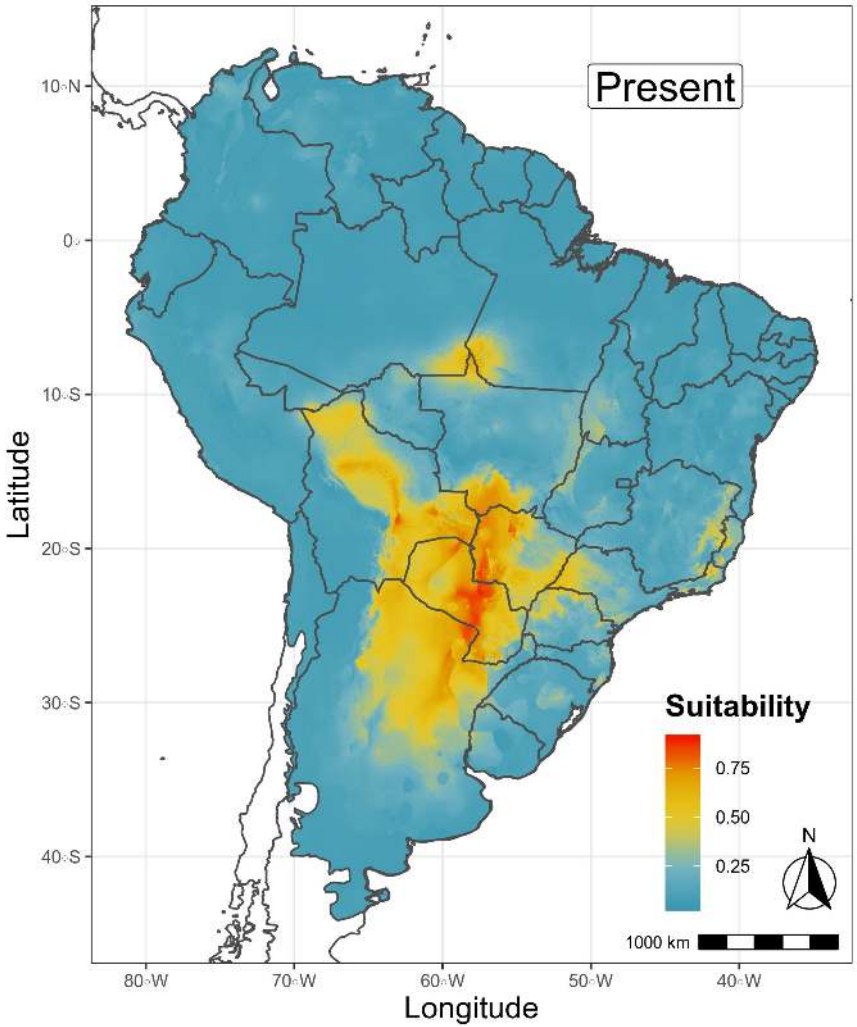



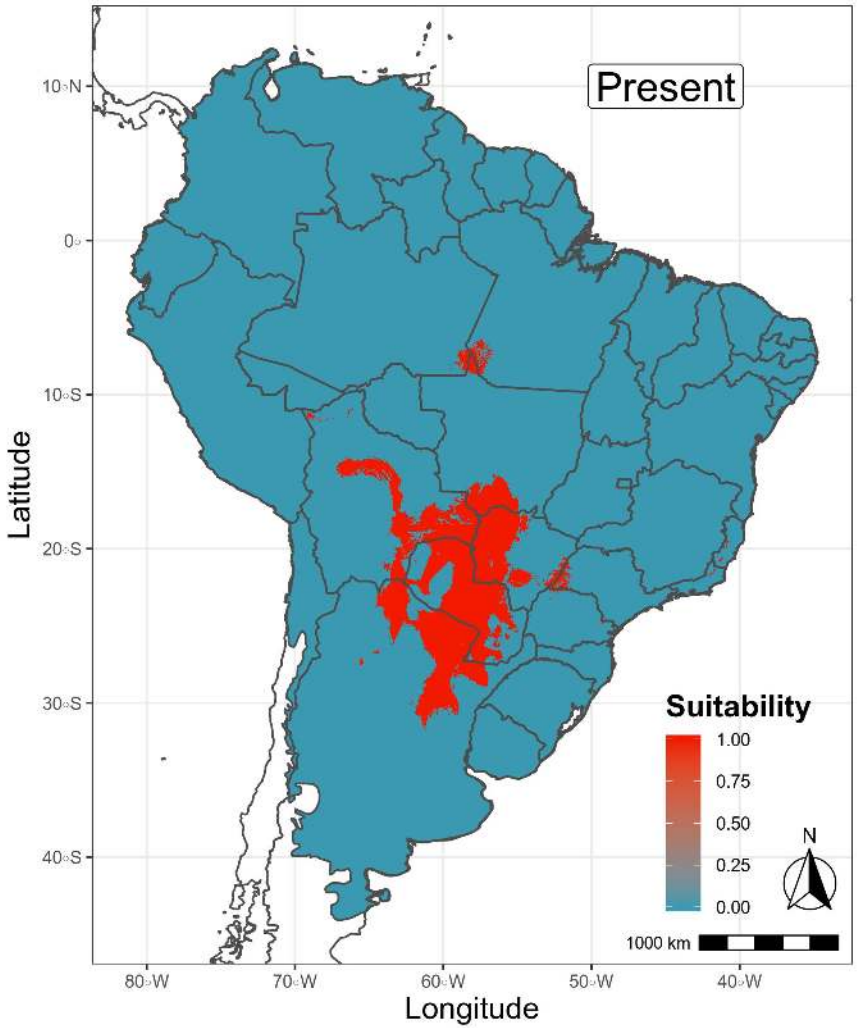



# Aplicações

## *Copernicia alba*



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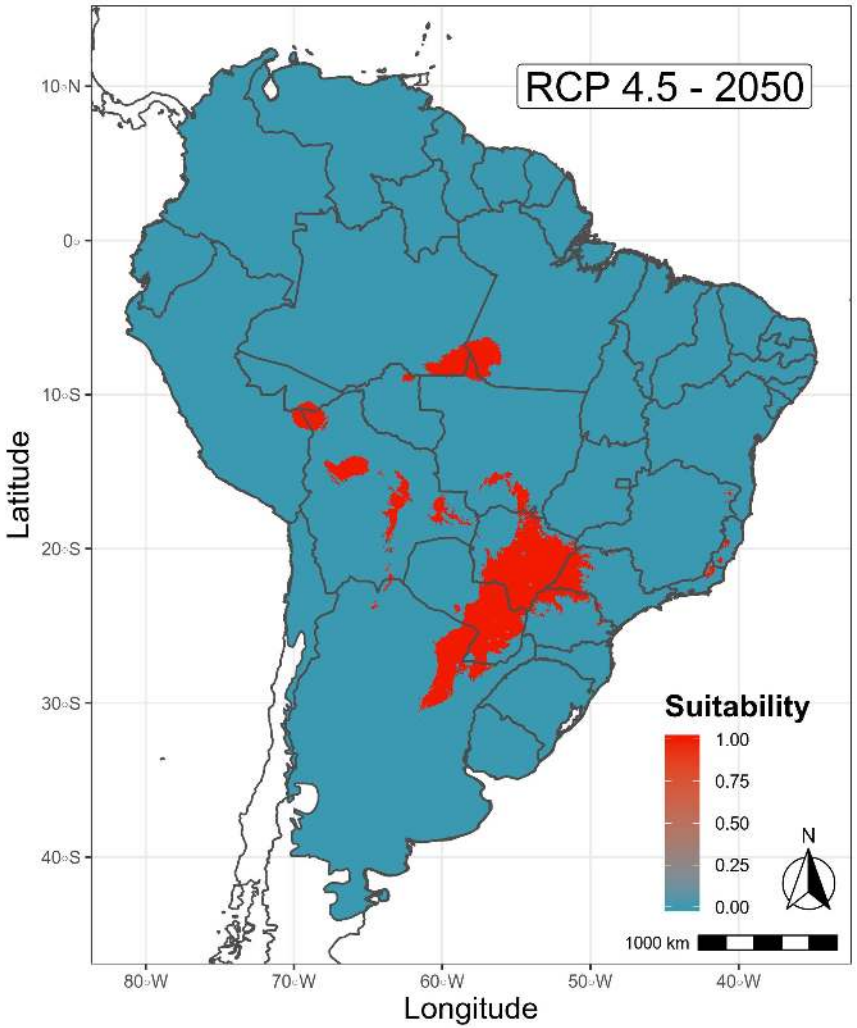
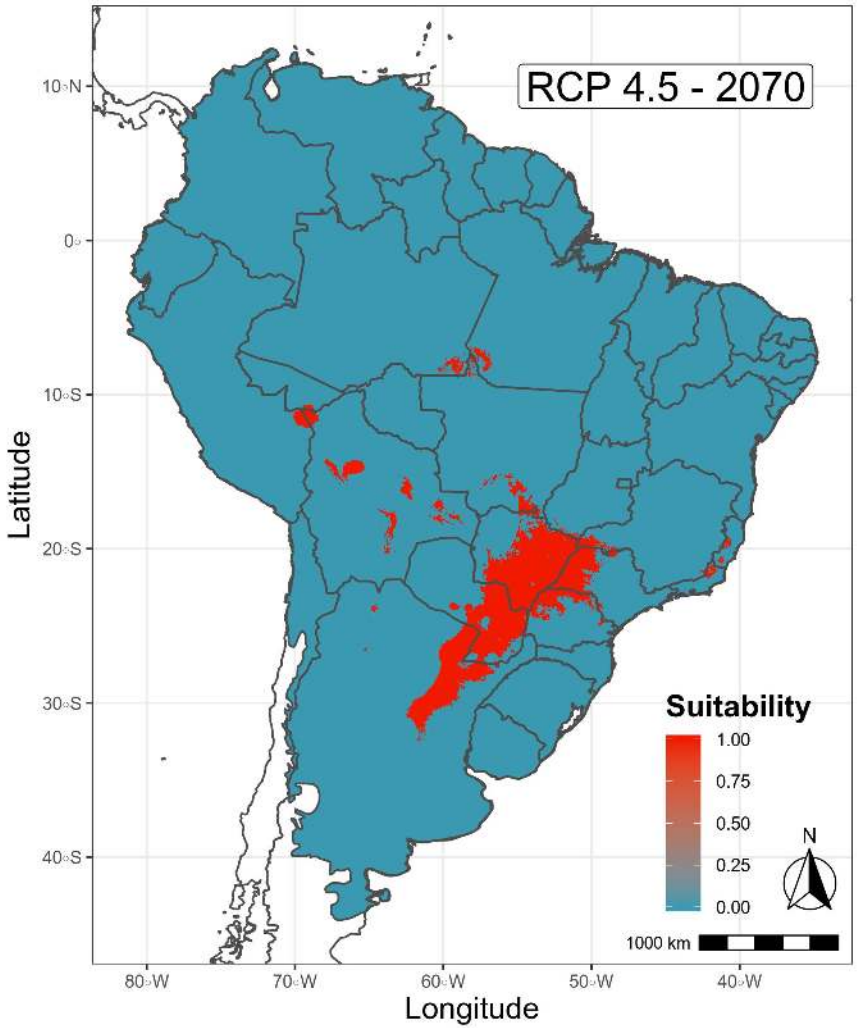
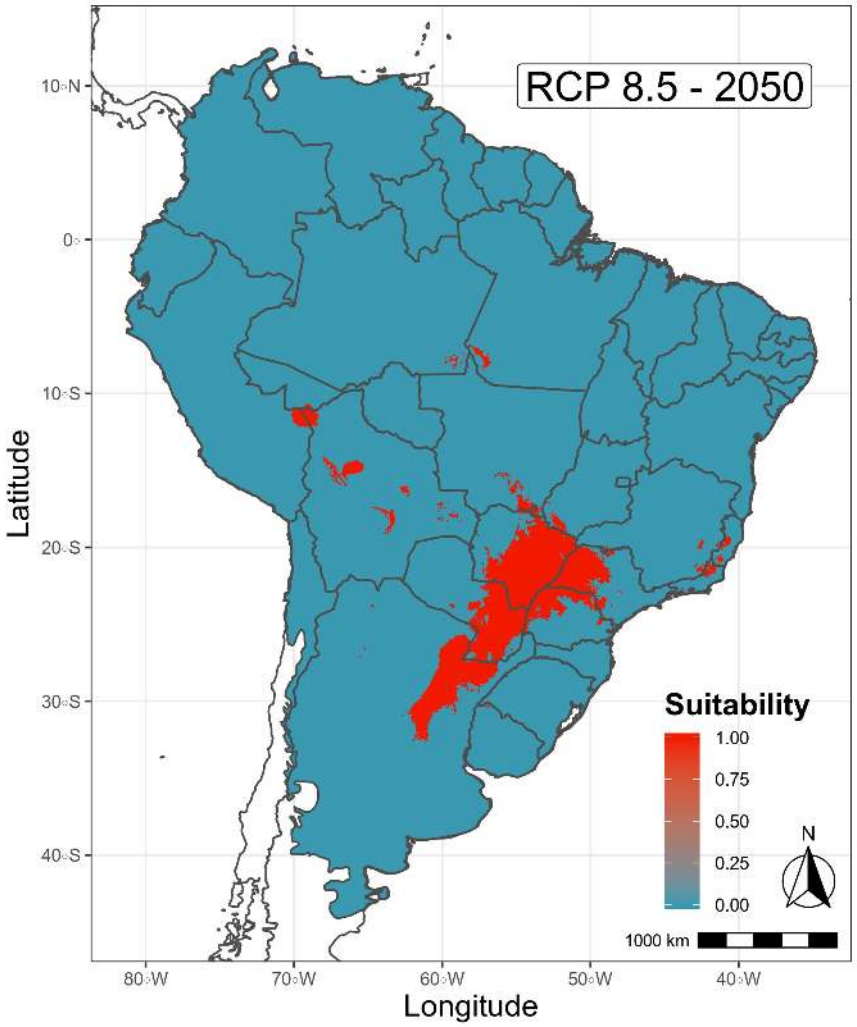
## *Copernicia alba*

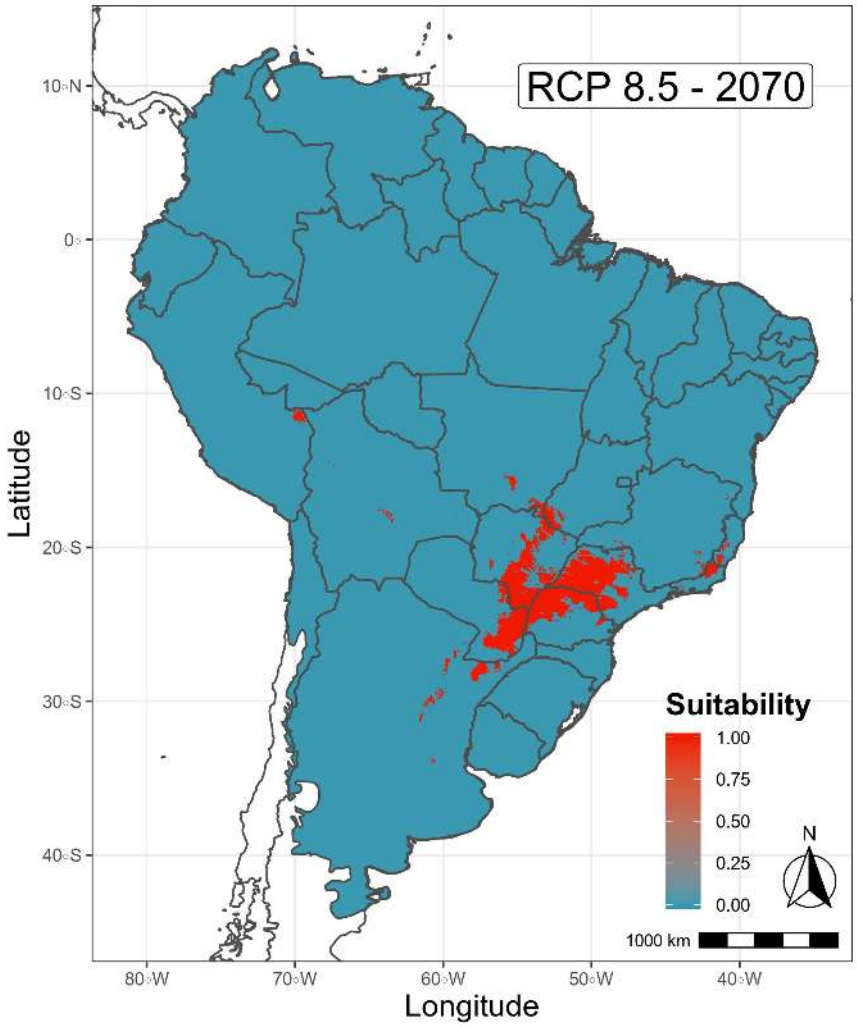


# Aplicações

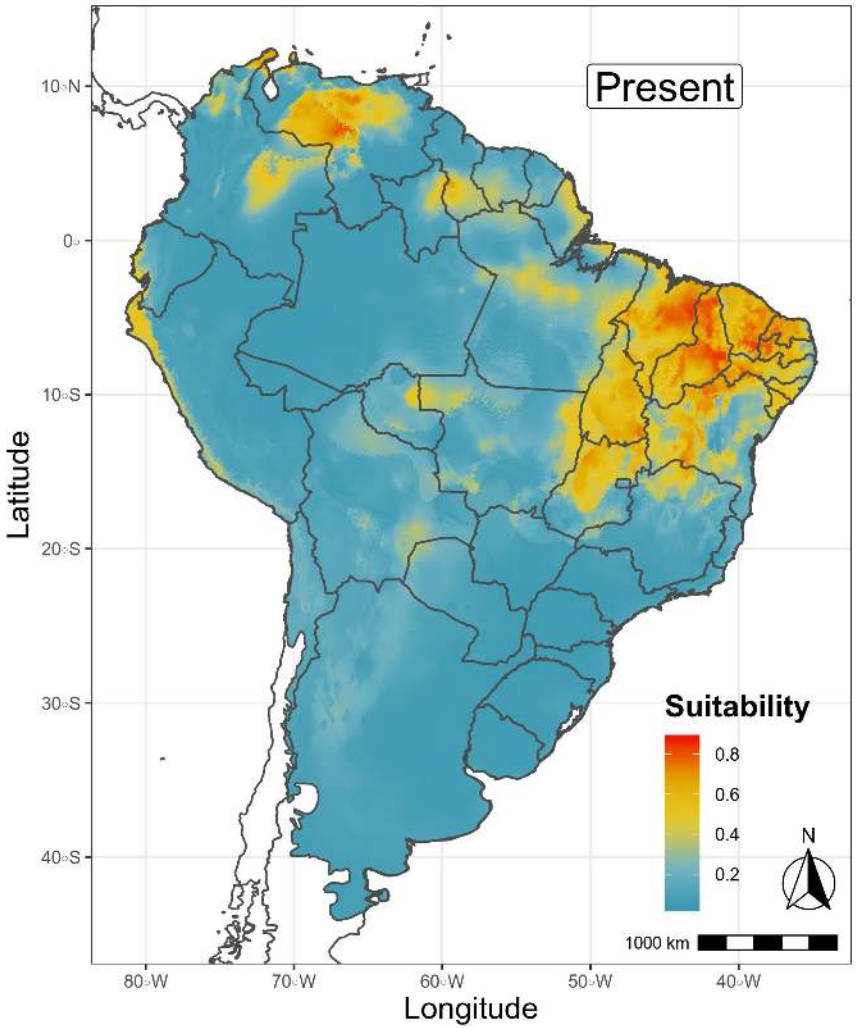
## *Copernicia alba*

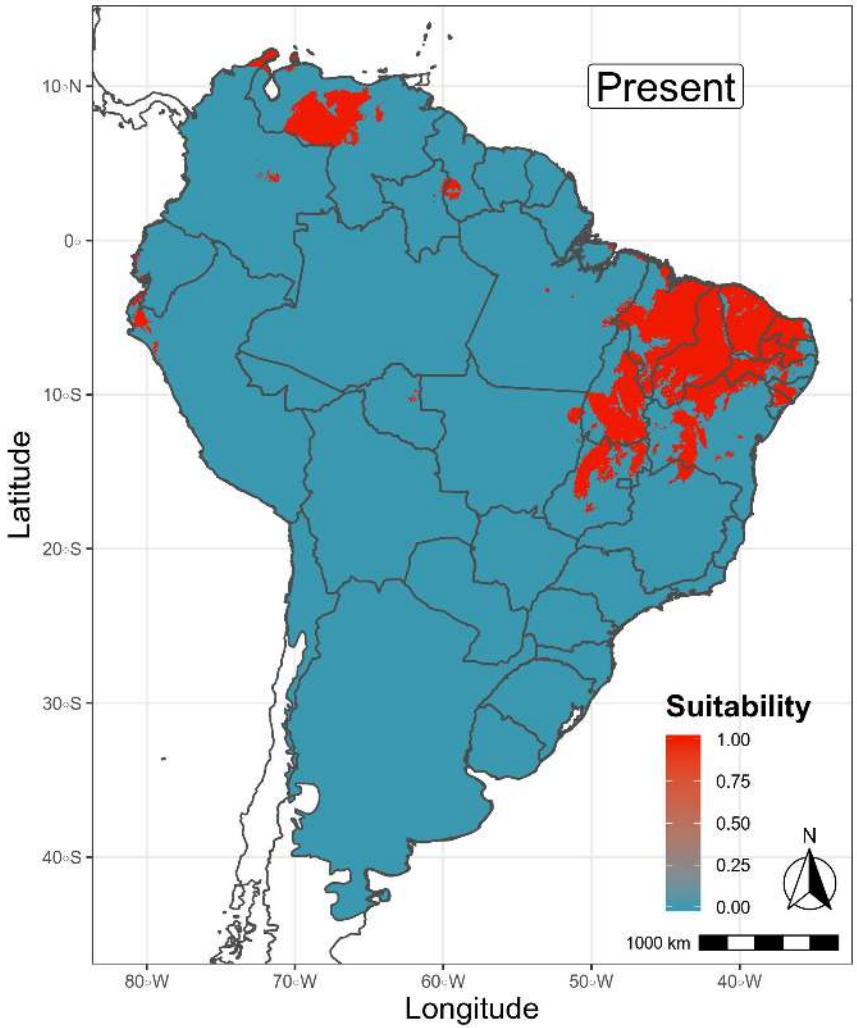


# Aplicações

## *Copernicia prunifera*



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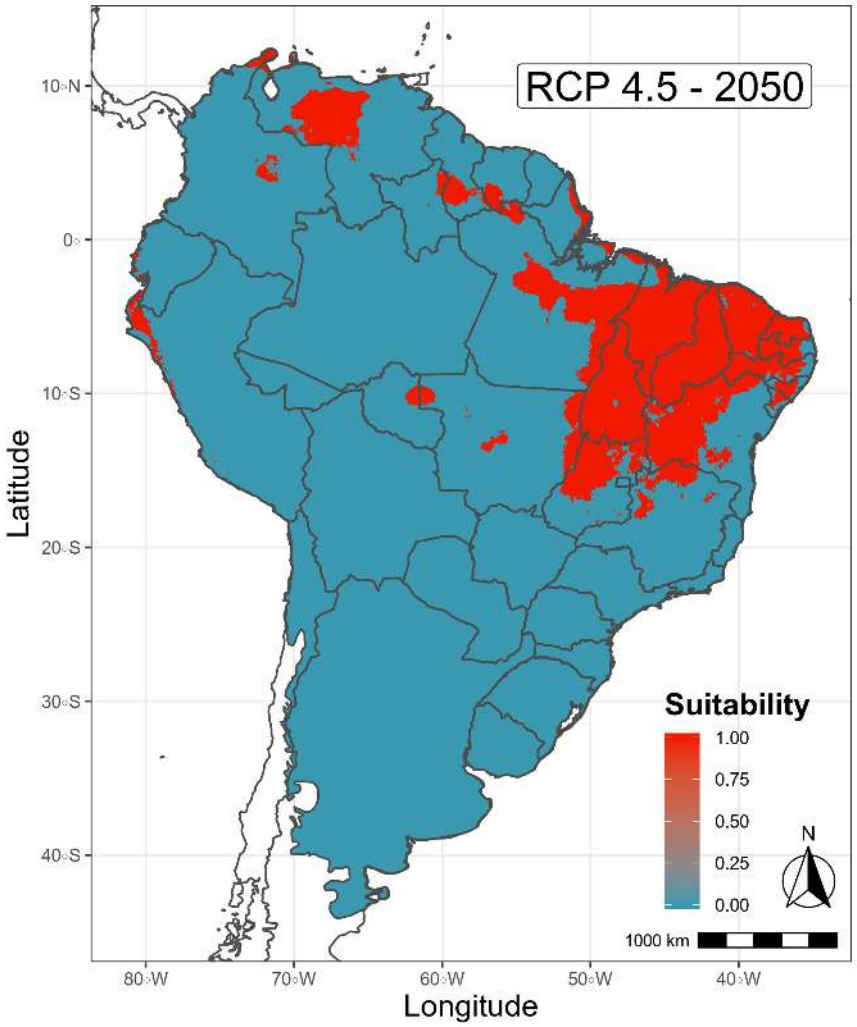


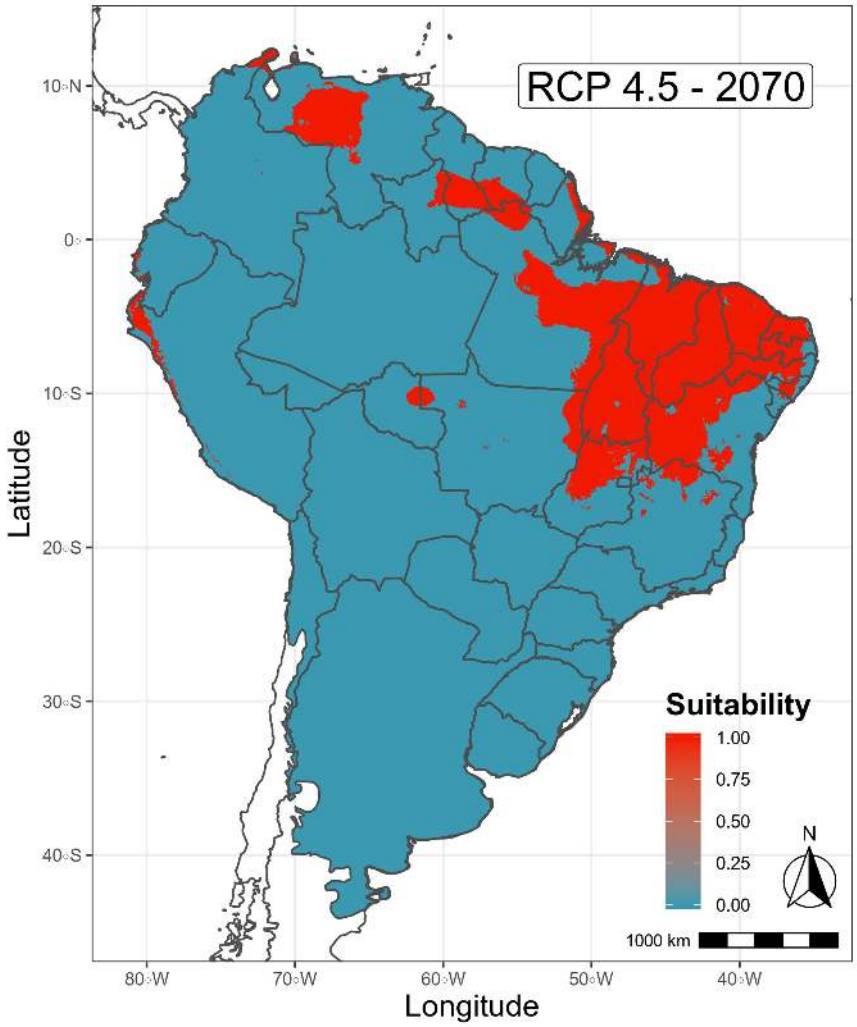

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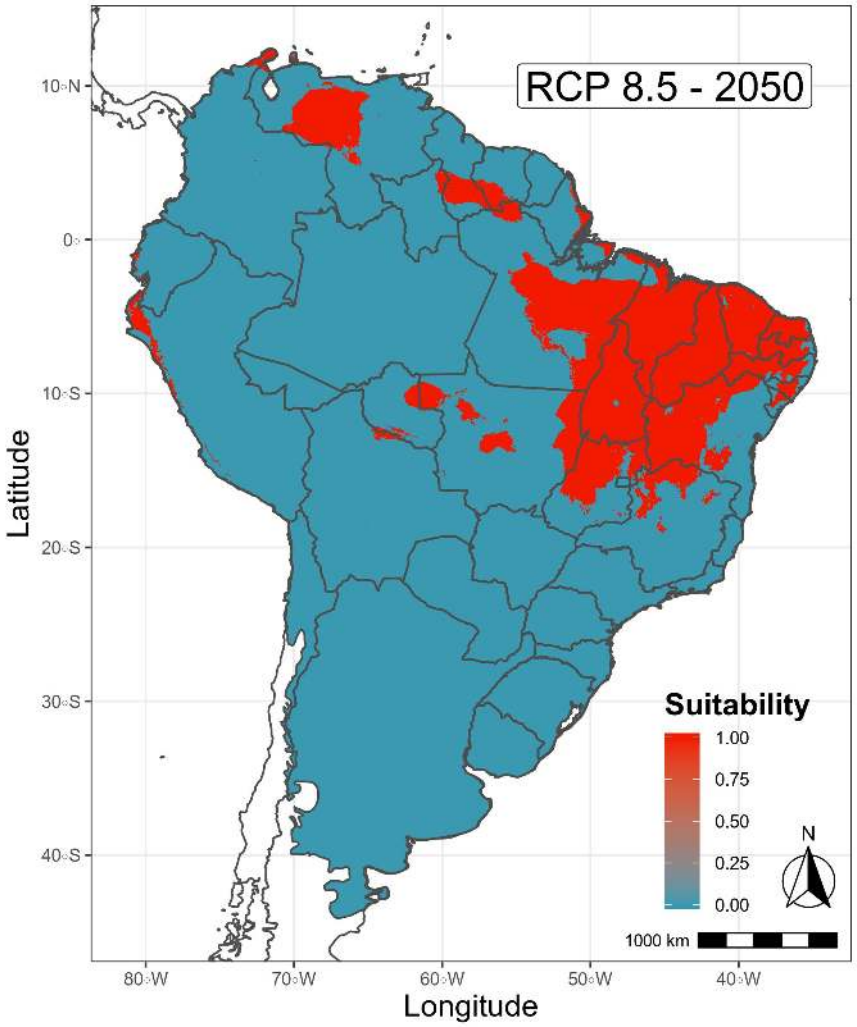
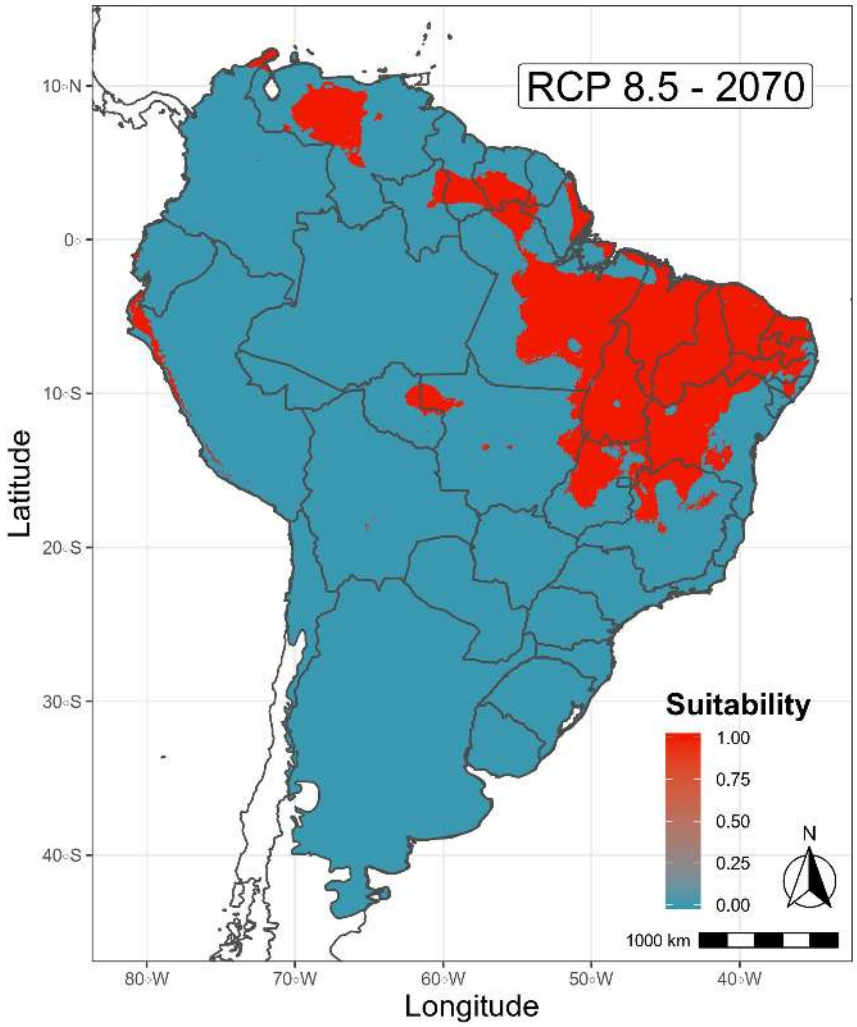


# Aplicações

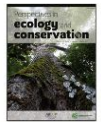
## Mineração sobre anuros e aves na Serra Espinhaço

ABECO
ASSOCIAÇÃO BRASILEIRA DE CIÊNCIA ECOLÓGICA E CONSERVAÇÃO

**Perspectives in ecology and conservation**

Supported by Boticário Group Foundation for Nature Protection

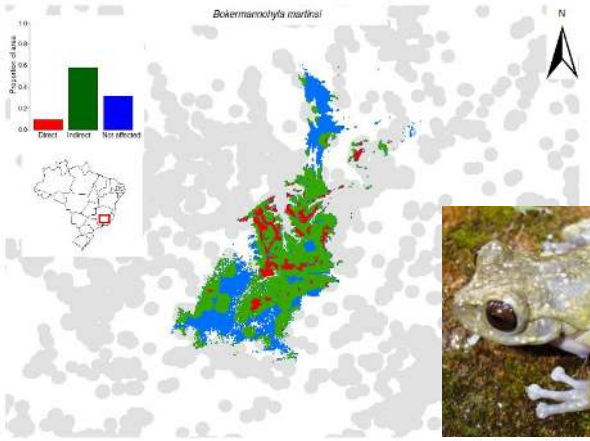
www.perspectecolconserv.com



### Impacts of mining activities on the potential geographic distribution of eastern Brazil mountaintop endemic species

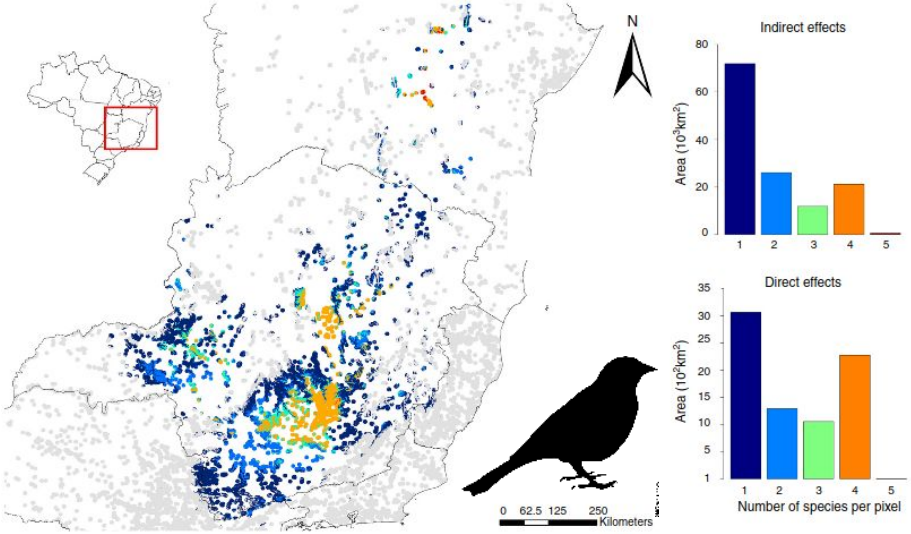
CrossMark

João Carlos de Castro Pena[a,b,*,1], Fernando Goulart[c], G. Wilson Fernandes[d,e], Diego Hoffmann[f], Felipe S.F. Leite[g], Natália Britto dos Santos[b], Britaldo Soares-Filho[c], Thadeu Sobral-Souza[h,i], Maurício Humberto Vancine[h], Marcos Rodrigues[a]



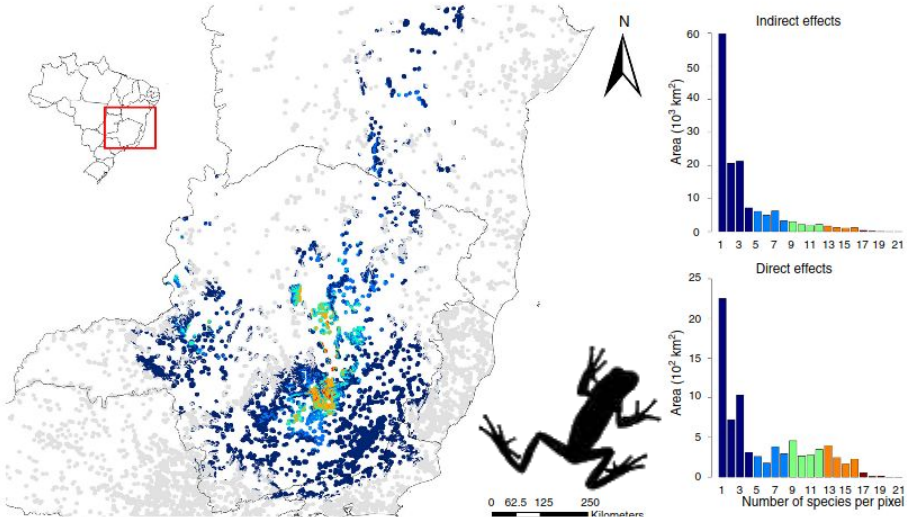



*Bokermannohyla martinsi*









# Aplicações

## Eficiência das áreas protegidas da AM e MA

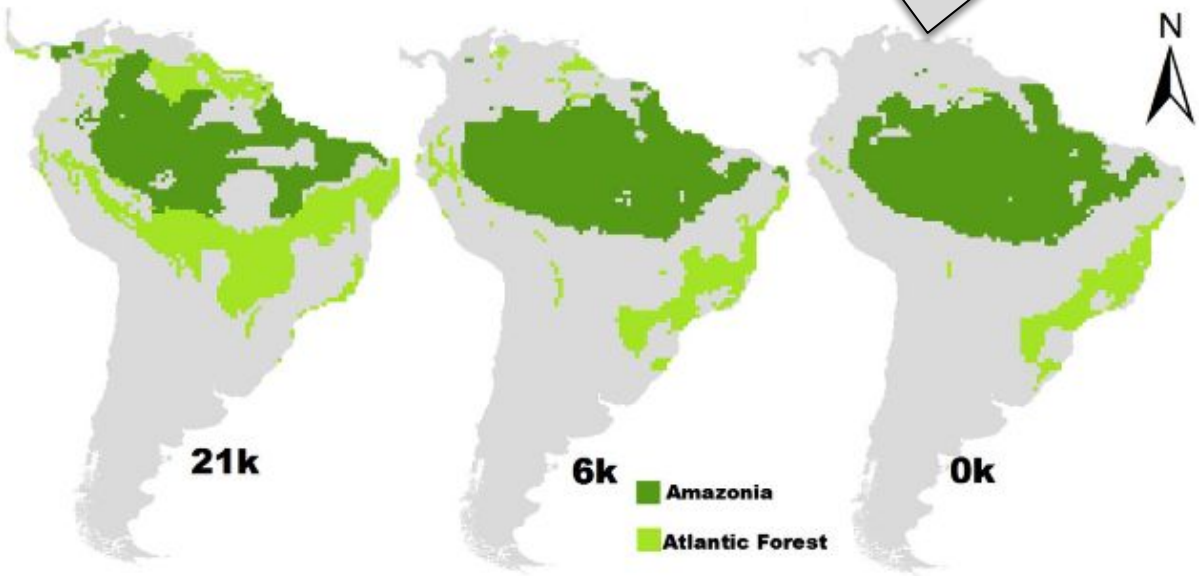
Contents lists available at ScienceDirect

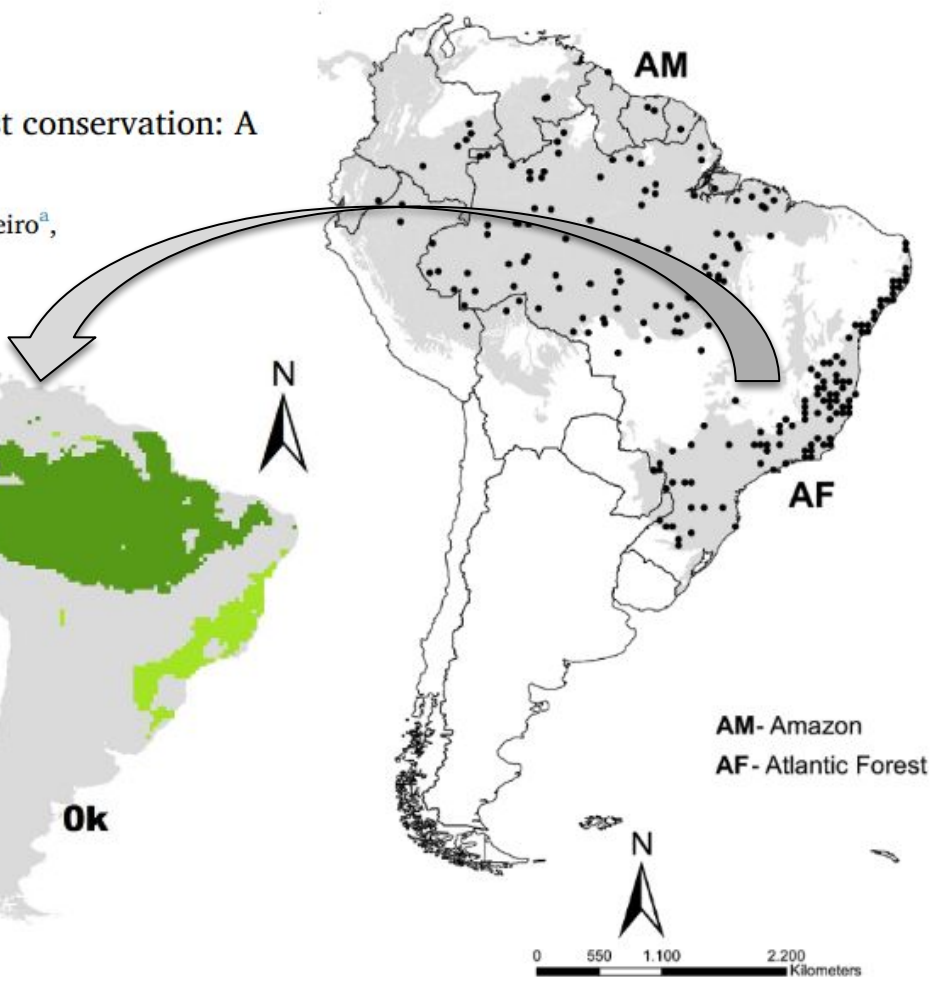
Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Efficiency of protected areas in Amazon and Atlantic Forest conservation: A spatio-temporal view

Thadeu Sobral-Souza[a,b,*], Maurício Humberto Vancine[a], Milton Cezar Ribeiro[a], Matheus S. Lima-Ribeiro[c]



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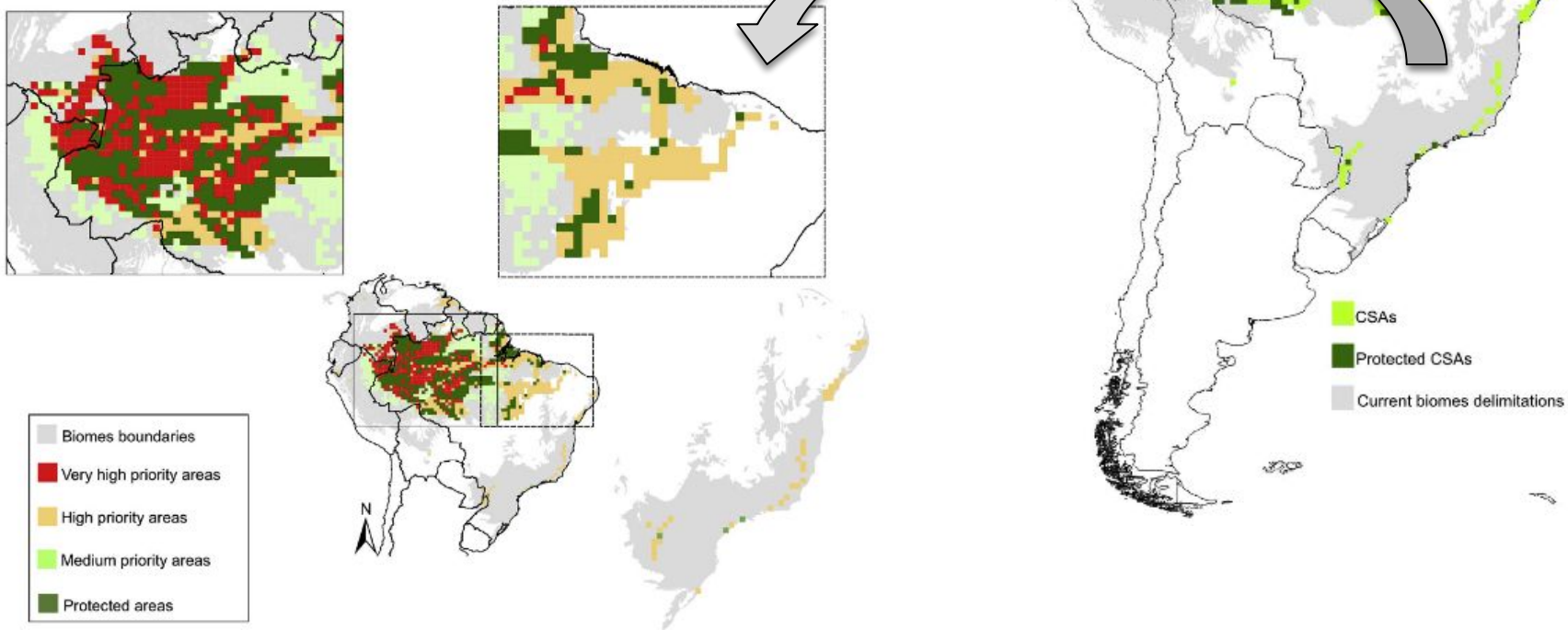


# Aplicações

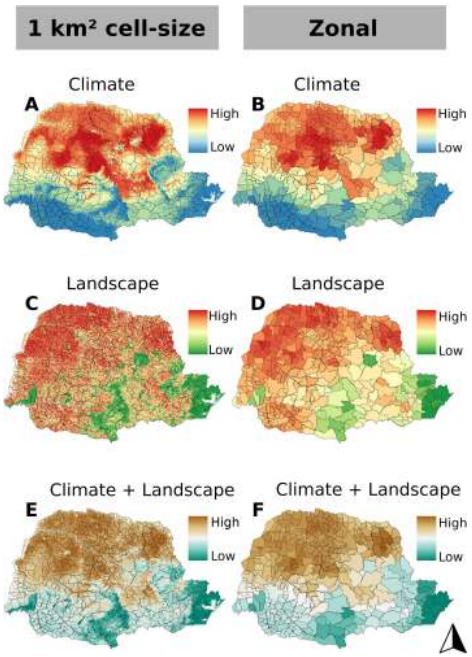
## Áreas de transmissão *Trypanosoma cruzi* no PR

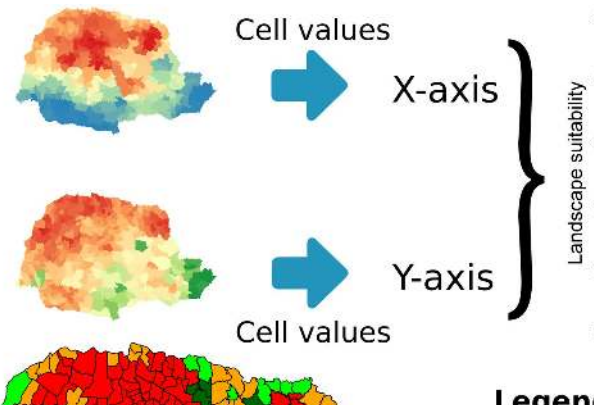
PLOS | NEGLECTED TROPICAL DISEASES

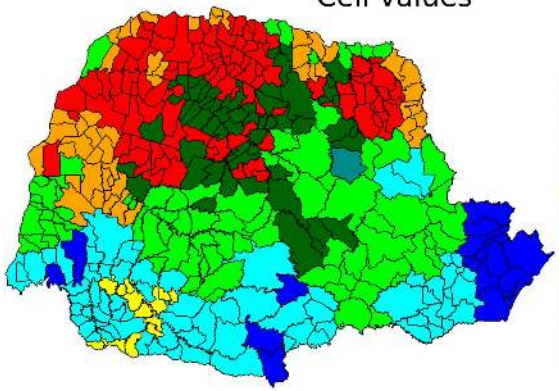
RESEARCH ARTICLE

Spatial prediction of risk areas for vector transmission of *Trypanosoma cruzi* in the State of Paraná, southern Brazil

**Andréia Mantovani Ferro e Silva[1], Thadeu Sobral-Souza[2], Maurício Humberto Vancine[2], Renata Lara Muylaert[2], Ana Paula de Abreu[1], Sandra Marisa Pelloso[1,3], Maria Dalva de Barros Carvalho[1,4], Luciano de Andrade[1,4], Milton Cezar Ribeiro[2], Max Jean de Ornelas Toledo[1,5]***



**Legend**

- High climate and high landscape suitability
- High climate and medium landscape suitability
- Medium climate and high landscape suitability
- Medium climate and medium landscape suitability
- Medium climate and low landscape suitability
- Low climate and high landscape suitability
- Low climate and mediumhigh landscape suitability
- Low climate and low landscape suitability

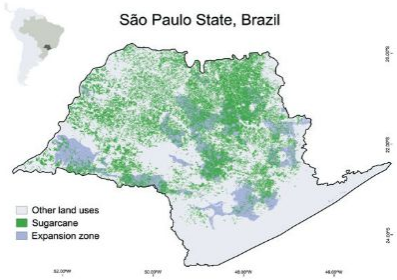
# Aplicações

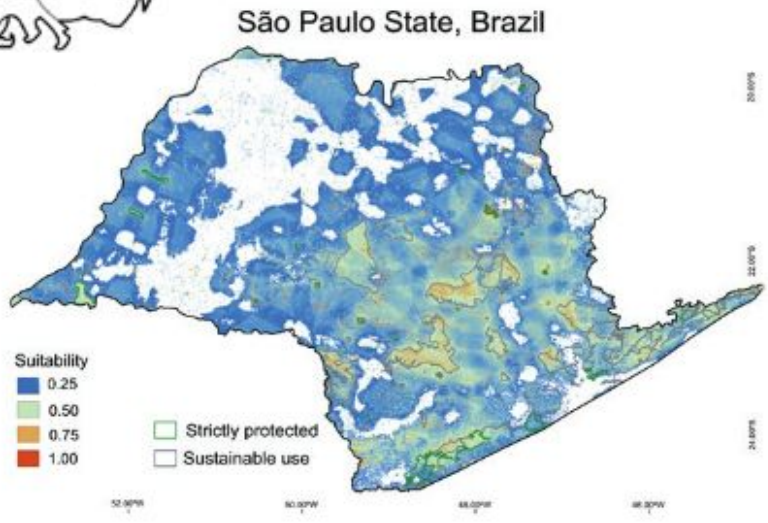
## Expansão da cana sobre o tamanduá em SP

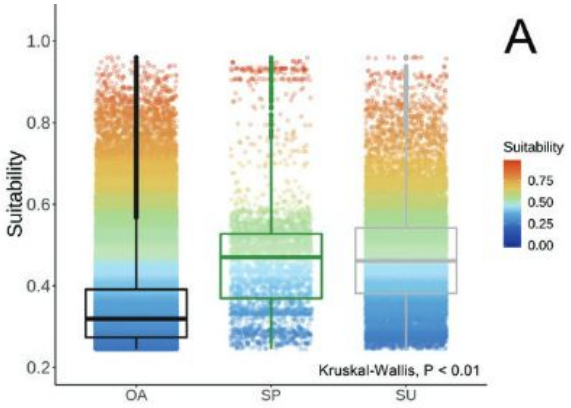
*Journal of Mammalogy*, XX(X):1–10, 2019
DOI:10.1093/jmammal/gyz042

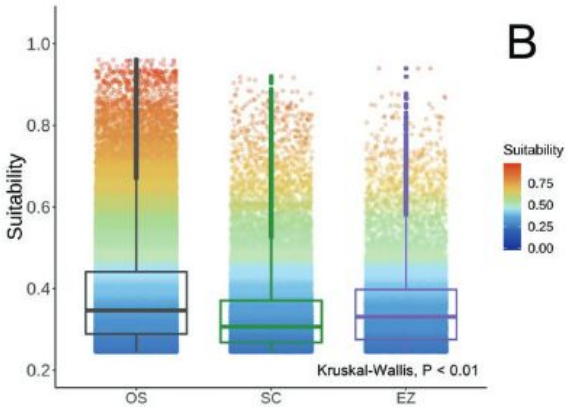
**Land-use changes and the expansion of biofuel crops threaten the giant anteater in southeastern Brazil**

Alessandra Bertassoni,* Rômulo Theodoro Costa, Jéssica Abonizio Gouvea, Rita de Cassia Bianchi, John Wesley Ribeiro, Maurício Humberto Vancine, and Milton Cezar Ribeiro

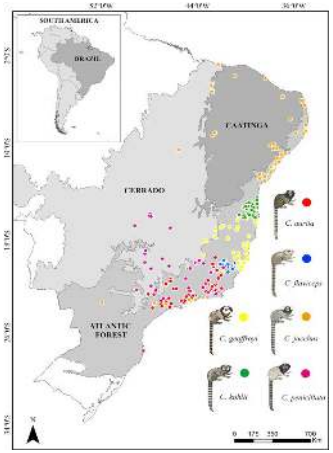



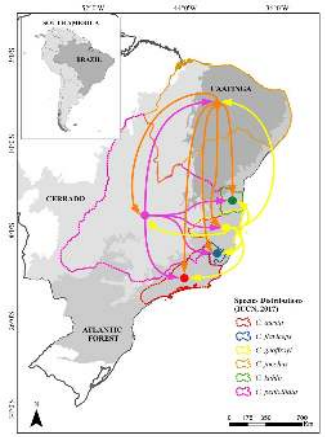



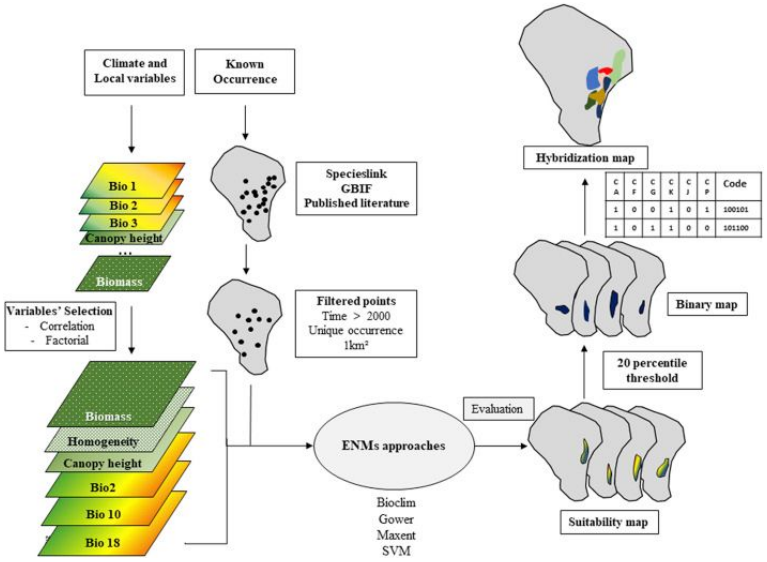



# Aplicações

## Zonas de hibridização potencial de saguis



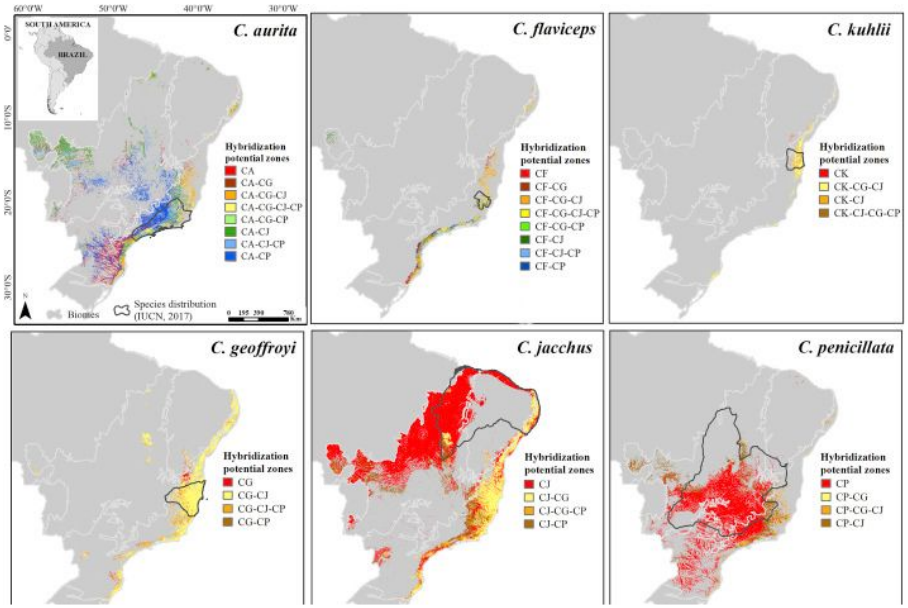

ELSEVIER

Global Ecology and Conservation

Volume 20, October 2019, e00706

### Predicting the potential hybridization zones between native and invasive marmosets within Neotropical biodiversity hotspots

Andreia Magro Moraes [a], Maurício Humberto Vancine [b], Andreza Magro Moraes [c], Carlos Leandro de Oliveira Cordeiro [d, e], Míriam Plaza Pinto [f], Adriana Almeida Lima [f], Laurence Culot [g], Thiago Sanna Freire Silva [e], Rosane Garcia Collevatti [h], Milton Cezar Ribeiro [a], Thadeu Sobral-Souza [i]



# Aplicações

## Efeitos sobre riqueza de borboletas

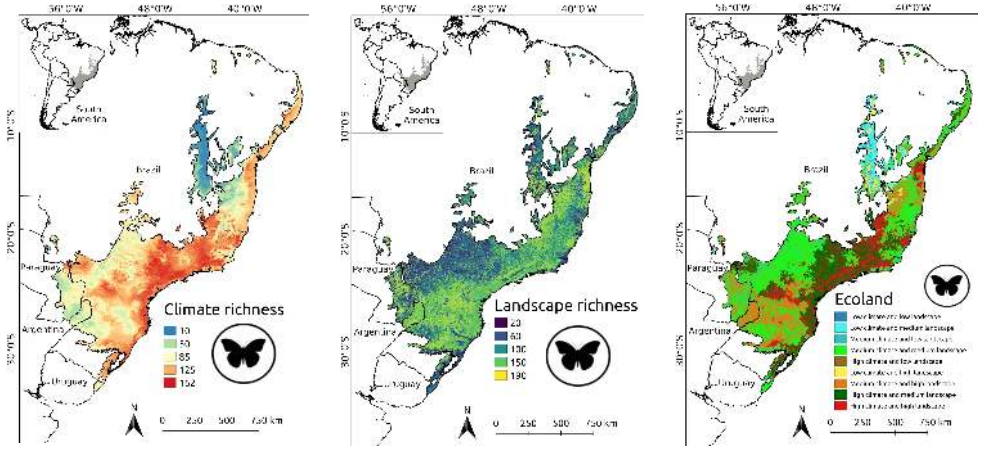
**Diversity and Distributions** Open Access — A Journal of Conservation Biogeography

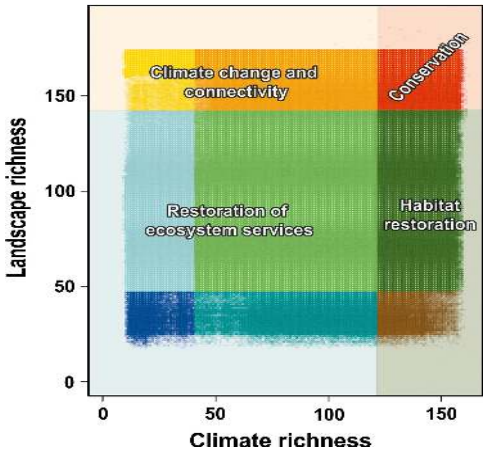
BIODIVERSITY RESEARCH | Open Access

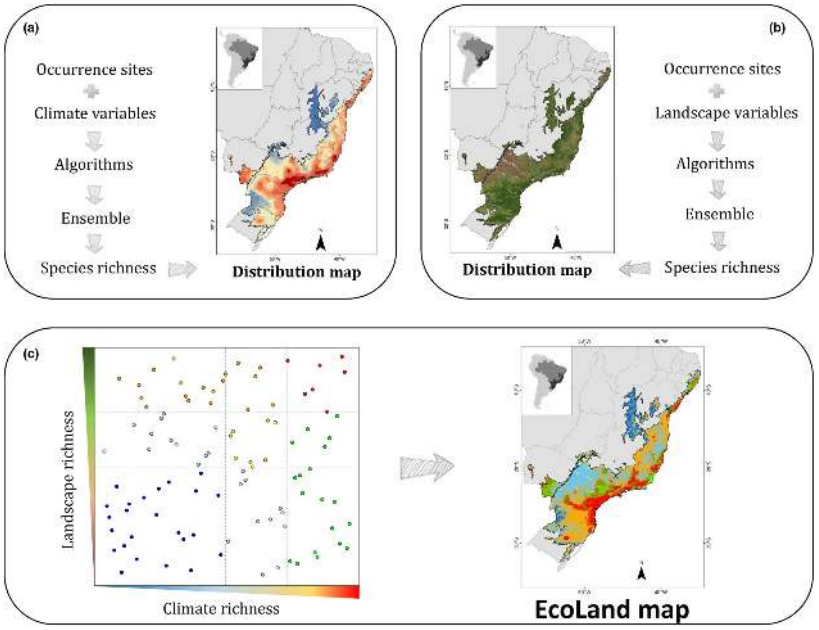
**Effects of landscape modification on species richness patterns of fruit-feeding butterflies in Brazilian Atlantic Forest**

Jessie P. Santos, Thadeu Sobral-Souza, Keith S. Brown Jr, Maurício Humberto Vancine, Milton C. Ribeiro, André V. L. Freitas

First published: 19 November 2019 | https://doi.org/10.1111/ddi.13007

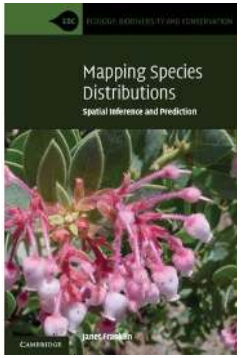


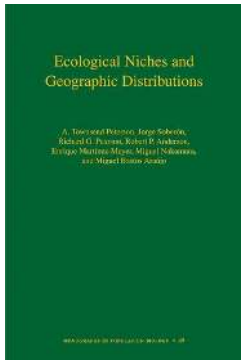



# Mais informações

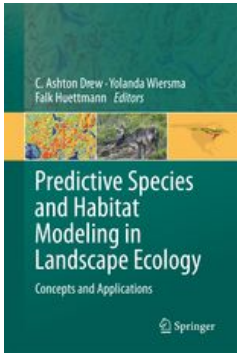
## Livros




Franklin (2009)

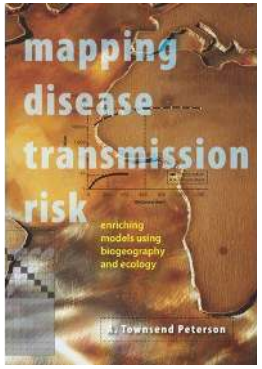



Peterson et al. (2011)

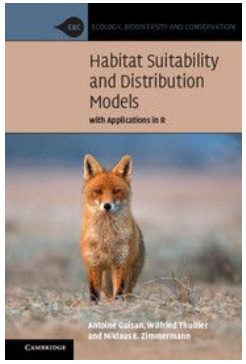



Drew et al. (2011)

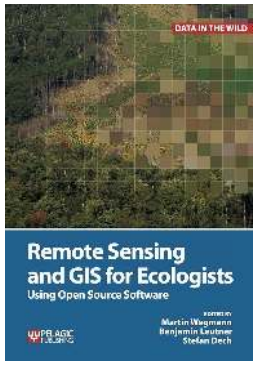

Lima-Ribeiro & Diniz-Filho (2013)



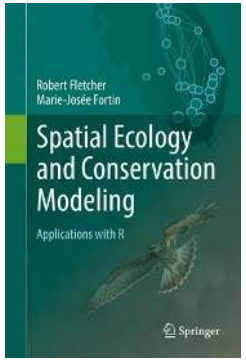

Peterson (2014)




Guisan et al. (2017)




Wegmann et al. (2016)
Cap. 13




Fletcher and Fortin (2018)
Cap. 07

# Muito obrigado!

## Modelos de Distribuição de Espécies: uma visão geral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